Editorial

Are Translations Useful?

The Translations Board is charged with evaluating AGU's program of translating Soviet and Chinese geophysical literature. To effectively complete this assignment, we need the help of AGU members who are familiar with current work in the USSR.

The general questions that we are addressing are the following:

1. Are translations an important part of AGU's overall publications program?
2. Are AGU translations used?
3. Are AGU members missing important results because they are not using AGU translations?
4. Are AGU translations covering the most relevant material?

There is a 'gut' feeling that the translations program is serving a useful purpose, but it is difficult to quantify the importance of this effort.

We are particularly anxious to know whether we are presenting a representative cross section of Soviet science. Are we providing access to the most useful papers by translating journals? Should we be moving more toward selected papers from journals? Would books be a more valuable source of information?

AGU's translations program began about 15 years ago. Currently, five Soviet journals are translated cover to cover: *Izvestiya, Physics of the Solid Earth*; *Izvestiya, Atmospheric and Oceanic Physics*; *Geotectonics*; *Oceanology*; and *Geomagnetism and Aeronomy*. Hydrology and geodesy are each covered by a journal of selected papers. Translations of three books have been published during the last 3 years. We have just begun publication of selected Chinese papers on earthquake research and related tectonic problems. A complete description of the program appears in the directory issue of *Eos* (November 4, 1980, page 741).

Translations are an expensive proposition. Although the number of subscribers is small, the program overall is not a financial drain for the Union and, in fact, makes a reasonable contribution to overhead. Individual publications are less healthy economically. We are seeking tests, in addition to financial viability, for assessing the worthiness of AGU's translations.

Are you familiar with Soviet research? Are you aware of AGU's translations? Do you use them? Can you assist us in evaluating the usefulness of the current program? Can you recommend directions for improving AGU's efforts?

Please send your comments and recommendations to me at

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The current statement of objectives for the translations program are reproduced below. The Board also welcomes comments on these objectives; these statements are the foundation for evaluating the program.

1. To make Soviet and Chinese geophysical literature available to those scientists whose command of English is better than their command of the original language in which the research was published.
2. Not only to provide access to the most interesting and useful science being done in the USSR and in China but also to provide a representative picture of what the current interest and level of progress is in these two countries.
3. To support the information needs of AGU members and scientists worldwide who require regional information in their disciplines.
4. Recognizing that the high cost of translation and production of translations generally places them outside the range of individual subscriptions, to provide the broadest possible access to this literature without a financial strain on the Union.

Peter Molnar, *Chairman*
Translations Board

The Jovian Magnetosphere: A Post-Voyager View*

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Introduction

At the Rice University Conference on the Physics of the Jovian Magnetosphere, interactive discussion among in situ observers, remote observers, and theorists was encouraged by means of an informal workshop format. This format was successful in promoting a useful degree of open discussion, but because of the informality of the conference format, neither an abstract book nor a conference proceedings is available for general distribution. In an attempt to bridge this information gap, I describe here several of the important results presented at the conference and attempt to characterize the emerging post-Voyager status of understanding of Jovian magnetospheric physics. A brief bibliography is provided for the reader who desires more detail. Included are pre-Voyager reviews and reference to many of the Voyager results.

The Io Torus

The 'Io torus' refers to a doughnut-shaped cloud of plasma and un-ionized gas that coincides, more-or-less, with the orbit of Io, Jupiter's innermost Galilean moon. It is generally agreed that the torus material is supplied by Io, especially by its 'volcanic' eruptions or geysers, which were discovered by Voyager 1. It is also generally agreed that heavy ions from the torus constitute the primary source of the plasma responsible for the inflation of Jupiter's outer magnetosphere. The torus has been observed remotely through its optical and UV emission lines by Earth-based and Earth-orbiting telescopes and by the Voyager 1 and 2 spacecraft. The composition, density, and temperature of the torus material have also now been measured in situ by the Voyager 1 spacecraft. The torus is found to consist primarily of oxygen and sulfur ions (presumably derived from the SO_2 exhausted from the geysers), with smaller amounts of sodium, potassium, and perhaps other, as-yet unidentified, elements. Both remote and in situ observations indicate a peak torus concentration of a few thousand ions per cubic centimeter and temperatures that range from 10^4 to a few times 10^5 K.

From Earth-based telescopic observations, C. B. Pilcher reported the detection of high-velocity jets of neutral sodium emanating outward from the satellite Io. These jets have ejection velocities of at least 4–5 km/s, well in excess of the gravitational escape velocity from Io (2.56 km/s). These sodium jets are thus considerably more energetic than the eruptive plumes discovered by Voyager 1, which do not generally attain escape velocity. The short lifetime of individual jet features implies the existence of a rapid loss mechanism operating on the neutral sodium—presumably electron impact ionization, which would imply a rapid and direct means of populating the outer plasma torus. It is not known whether the jets originate from a highly localized sputtering process or from eruptive outgassing events similar to, but more energetic than, the geysers observed by Voyagers 1 and 2.

B. R. Sandel reported Voyager ultraviolet observations of doubly ionized sulfur emission, which delineates the hotter regions of the torus (~10^6 K), as compared to the relatively cool regions (~10^4 K) responsible for the optical emissions from singly ionized sulfur observable from Earth. The UV emissions exhibit a local-time asymmetry, with the duskside torus appearing 50% brighter than the dawnside in the Voyager observations. If this asymmetry proves to be persistent, its explanation will provide quite a challenge to theorists because the torus, located only 6 Jovian radii (R_J) from Jupiter, is thought to be well insulated from the perturbing effects of the solar wind, which become important beyond 40 or 50 R_J; it is difficult to explain local-time asymmetries without invoking solar wind effects. (The day-night asymmetry of the solar heating of Jupiter's atmosphere could also, in principle, produce a local-time effect, but the energy involved in solar heating appears to be negligible in comparison with the total energy budget of the torus.)

The UV torus emissions observed by Voyager apparently do not exhibit the longitudinal asymmetry (corotating with Jupiter) apparent in the optical emissions observed from Earth. On the other hand, the auroral emissions from Jupiter's atmosphere, thought to be excited by electrons that precipitate from the torus, do appear to have such an asymmetry, being brightest in the longitude range $195° \leq \lambda_{III} \leq 235°$ (although a possible effect attributable to viewing geometry cannot yet be ruled out). It is of interest to note that this longitude range corresponds to the 'active sector' of Jupiter's atmosphere that had been identified earlier from remote radio observations and from Pioneer 10 and 11 observations; the active sector plays a fundamental role in the 'magnetic anomaly model' of Jupiter's magnetosphere that is described below.

D. E. Shemansky demonstrated that Voyager UV observations do not show a dramatically enhanced intensity in the near vicinity of Io, and this negative result implies an upper limit to the plasma injection rate at Io that is 2 orders of magnitude lower than earlier estimates of the plasma injection rate that were based upon optical observations and observed departures from ideal corotational flow (see below). R. A. Brown suggested that these disparate results could be reconciled if the sulfur and oxygen plasma were injected not directly from Io but from a broadly distributed neutral gas cloud spread over a significant fraction of Io's orbit, similar to the neutral sodium cloud that has been observed. Shemansky also noted that the UV observations indicate a sulfur-to-oxygen abundance ratio of 0.6, consistent with the idea that most of the sulfur and oxygen plasma derives from dissociative ionization of the sulfur dioxide that is a principal component of the 'volcanic' emissions of Io.

G. L. Siscoe and F. Bagenal presented Voyager 1 in situ measurements of the heavy-ion torus plasma, largely confirming plasma parameters (density, temperature, and composition) that had been inferred from remote optical and UV observations. Bagenal noted that the abundance ratio S/O ~ 0.6, inferred from UV observations, would be consistent with the local plasma measurements if one assumes that the O^+ and S^+ ions are injected with a common thermal velocity rather than at a common temperature. This common-velocity injection would be expected if the induced electric field caused by plasma corotational motion past Io were the primary energy source for the ions, as illustrated in Figure 1. Siscoe also noted that this interpretation of the Voyager 1 plasma data would imply that the ions were picked up

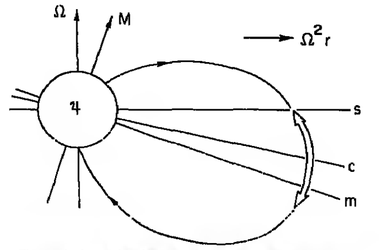

Fig. 2. Latitudinal oscillations of Io torus plasma discussed by A. J. Dessler. The centrifugal acceleration $\Omega^2 r$ has no field-aligned component at the 'centrifugal equator' (c), which lies between the magnetic equator (m) and the spin equator (s). Plasma from Io is generally injected near s and thus executes field-aligned oscillations about c.

Fig. 1. Illustration of the 'pick up' of newly ionized atoms by the corotation electric field. If the atom is initially at rest (as illustrated), the resulting motion consists of a superposition of E × B drift and cyclotron motion, each having speed $E/B = \omega r$. If the atom were initially moving with the Keplerian orbit velocity v_K in the corotation frame, the cyclotron motion would have the reduced speed $E/B - v_K$. The electrons execute cycloids with the opposite sense but with cyclotron radii too small to illustrate on this scale.

(Figure 1) in a region where the flow velocity was only ~25% of the corotation velocity at Io's orbit and thus inferred the existence of a region of reduced rotational flow near Io that would be caused by the large inertia of freshly-injected plasma. (The rotational flow velocity near Io's orbit was observed to be very nearly equal to the local corotation velocity, as reported by R. L. McNutt (see below), but the velocity observation was not made in the immediate vicinity of Io itself.)

A. J. Dessler interpreted observed irregularities in plasma density in terms of a model of latitudinal plasma oscillations about the equatorial plane, which are analogous to the oscillations of a pendulum in the artificial gravity field associated with the centrifugal force of corotation (Figure 2).

G. L. Siscoe noted that the portion of the torus outside Io's orbit is at least 10 times hotter than that inside Io's orbit and that this difference is most easily explained by assuming that outward radial transport is much faster than inward radial transport. Siscoe and J. D. Richardson have modeled this transport in terms of a diffusion process wherein the outward diffusion rate is enhanced by a factor of 50 relative to the inward diffusion rate as the result of a centrifugally driven interchange instability (essentially equivalent to the Rayleigh-Taylor instability of a heavy fluid floating on a lighter fluid, except that 'gravity' here is outward, owing to the centrifugal force of corotation). T. W. Hill proposed an alternative description of this rapid outward transport in terms of a convection system driven by azimuthally asymmetric mass loading of the torus (Figure 3).

M. L. Acuña presented an analysis of Voyager 1 magnetometer measurements indicating that a current ~3×10^8 A links Io to Jupiter's ionosphere. Such a current, driven by the 400-kV EMF produced by the relative motion between Io and the corotating magnetosphere, would draw energy from that relative motion at a rate of ~10^{12} W. By comparison, Siscoe and others estimated that the torus dissipates a total power approaching 10^{14} W, through its aurorel emissions in addition to its local optical and UV emission. M. G. Kivelson argued that the magnetometer observations would be consistent with a much smaller current (~7×10^6 A) if the current were distributed through a larger region than the Io magnetic flux tube.

Acuña also showed evidence of extended wakelike disturbances in the corotational flow downstream of Ganymede, the third of Jupiter's Galilean moons. These disturbances exhibit 6%–10% depressions of the magnetic field and associated plasma signatures that are sometimes, but not always, consistent with diamagnetic depressions. The disturbances also show evidence of energetic-particle acceleration or trapping within the magnetic cavities. The disturbances have apparent dimensions much larger than the geometrical wake of Ganymede itself, and the origin and nature of the interaction are not well understood.

R. M. Thorne showed that the whistler-mode plasma wave turbulence observed in Io's torus by Voyager 1 would produce rapid precipitation of torus electrons into Jupiter's atmo-

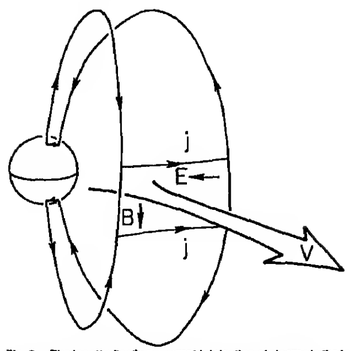

Fig. 3. The longitudinally asymmetric injection of plasma in the Io torus produces a partial ring current, which closes by means of field-aligned currents connecting to Pedersen currents in Jupiter's ionosphere. The closure of the Pedersen current requires an electric field E, which is associated with outward drift $v = E \times B/B^2$. An inward return flow toward Jupiter occurs in the opposite longitude sector (not shown). The convection pattern corotates with Jupiter and provides a mechanism for rapid outward transport of the Io torus plasma (T. W. Hill), while the associated field-aligned currents may produce decametric or kilometric radiation (A. J. Dessler).

sphere. In addition to accounting for the observed auroral emissions from Jupiter, this precipitation would imply the existence of a rapid radial transport of ionization mechanism to replace the electrons lost into the atmosphere on a time scale of 1 day.

T. V. Johnson discussed a model of electrostatic charging (by electron impact) of dust particles carried aloft by Io's eruptive plumes. He estimates that submicrometer-size dust particles may be charged up to ~10 V, sufficient for the Lorentz force to overcome Io's gravity and allow the dust particles to escape directly to the magnetosphere. The subsequent breakup of such particles would directly provide a distributed source of sulfur and oxygen to the torus. The mass output of the plumes (~1000 kg/s) appears sufficient to maintain the observed plasma torus against loss by outward transport.

L. J. Lanzerotti reported laboratory measurements of the sputtering of SO_2 ice by incident 1.5-MeV ions, indicating that incident O^+ ions produce a remarkably high yield of ~4000 sputtered atoms per incident ion. This result suggests that the Io torus may sustain itself to a large degree by heavy-ion sputtering of material from the SO_2-enriched surface of Io.

Low-Frequency Radio Emissions

'Decametric' (wavelength $\lambda \sim 10$ m) radio emissions from Jupiter have been observed extensively by earthbound radio teloscopes for over two decades, and they have provided much indirect evidence about Jupiter's magnetosphere, and especially its interaction with Io. The occurrence rate and intensity of decametric radio storms depend strongly on both the Jovian longitude of the observer and the orbital phase of Io relative to the observer. These correlations have given rise to models wherein the radiation is emitted in a narrow conical beam nearly perpendicular to the magnetic field near the foot of the Jovian magnetic flux tube that intersects Io. The energy source for the emission is widely considered to be an electron beam associated with the magnetic-field-aligned current that connects Io with Jupiter's ionosphere, the current being driven by the EMF associated with the relative motion between Io and the corotating magnetospheric plasma. Radio receivers on Earth-orbiting satellites, and on Voyagers 1 and 2, have now extended these decametric observations to longer wavelength regions of the spectrum—hectometric ($\lambda \sim 100$ m) and kilometric ($\lambda \sim 1$ km). The Voyager receivers have also provided a new viewing perspective on the post-encounter trajectories in the predawn sector of Jovian local time.

T. D. Carr reviewed recent ground-based and Voyager-based radio observations, noting that the Io-orbital phase control tends to disappear at lower frequencies (hectometric and kilometric) and that new Voyager observations indicate an apparent local-time dependence superimposed on the known Jovian-longitude dependence of the radio sources (see below). He also pointed out that the location(s) of the source regions has not been definitively established for any of the low-frequency radio emissions. It was noted by J. Alexander that the observed frequency and polarization characteristics would place most if not all known emission sources at low altitudes in Jupiter's northern hemisphere (with the possible exception of the narrow-band kilometric component; see below).

J. R. Thieman observed that the decametric (10 MHz) Io-dependent sources appeared at the same Jovian longitudes in pre- and postencounter Voyager observations as they did in Earth-based observations, thus supporting the traditional view that the radio sources corotate with Jupiter and are independent of local time. On the other hand, he noted that the Io-independent component seems to shift toward smaller longitudes in the postencounter observations, as if there were a local-time dependence of the strength of the various source regions. This result would present theoretical difficulties comparable to those noted above in connection with the apparent local-time dependence of the UV brightness of the Io torus.

Similarly, the broadband kilometric component, discovered by Voyager 1 and described by M. D. Desch, exhibits an apparent local-time dependence. The pre- and postencounter observations are clearly different with regard to polarization sense (LH before encounter, RH after) as well as emission probability and intensity (smaller after encounter than before). These results were interpreted in terms of a model in which the postencounter observations are attributed to over-the-pole viewing of the same dayside source that produced the preencounter observations when viewed directly from local noon (Figure 4). Some skepticism was expressed about the plausibility of this over-the-pole viewing geometry, but an alternative explanation of the difference between pre- and postencounter observations in terms of a latitude effect also has implausible features. A satisfactory explanation for the observations was not immediately apparent.

M. L. Kaiser described a narrow-band kilometric wave component (also discovered by Voyager 1) whose source apparently rotates 3%–5% slower than the rigid System III (1965) rotation rate that is characteristic of all other known Jovian radio sources. From this rotation lag, and from considerations of propagation and viewing geometry, Kaiser infers that the source of the narrow-band kilometric component is located near the outer edge of the Io plasma torus in the magnetospheric equatorial plane rather than at the high-latitude Jovian ionosphere, as is thought to be the case for the other low-frequency sources.

It was noted by Alexander and by C. K. Goertz that the decametric emissions, and especially the Io-independent component, often occur at frequencies above the cyclotron frequency of electrons in the strongest magnetic field accessible to trapped electrons, the implication being that the emission is caused not by trapped electrons but by precipitating electrons.

A. J. Dessler noted that the magnetic anomaly model, in which plasma is produced preferentially in a particular active sector of Jovian longitude, predicts a partial ring current in the Io torus (Figure 3), which in turn produces magnetic-field-aligned current densities of ~1/4 A/km², similar to the magnitude of current density that is known to produce terrestrial kilometric radiation.

M. L. Goldstein proposed a mechanism to account for the arc-shaped features in the dynamic spectra observed by the Voyagers, involving an emission cone angle that depends on frequency. D. A. Gurnett further proposed that the observed multiplicity of these arc emission features might be produced by multiple bounces, between northern and southern Jovian hemispheres, of a large-amplitude Alfvén wave produced by the interaction between Io and the corotational magnetospheric flow.

Kaiser also announced the first definitive observation (by the Voyager 1 and 2 planetary radio astronomy experiments) of radio emissions from Saturn. The emissions were observed at 200 kHz, and Kaiser noted that Saturn as a radio emitter looks much more like Earth than like Jupiter.

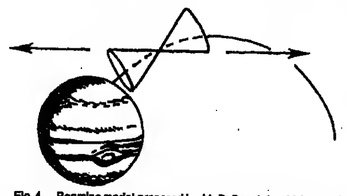

Fig. 4. Beaming model proposed by M. D. Desch in which broadband kilometric radiation is emitted along the surface of a cone that may intersect the observer either on the same side of Jupiter (to the right) or over Jupiter's pole (to the left). It is proposed that the emission is most probable and/or most intense on the dayside of Jupiter; the difference between direct and over-the-pole viewing geometries would then explain the differences between preencounter and postencounter Voyager observations.

Plasma Flow and Rotational Dynamics

The Pioneer 10 and 11 encounters (1973–1974) confirmed earlier suspicions that the corotation of the magnetospheric plasma with the planet would produce more important dynamical effects at Jupiter than at Earth, primarily because of the larger size and faster rotation rate of Jupiter. Voyager 1 and 2 (1979) measurements, on the other hand, have now confirmed recent theoretical suggestions that corotation in Jupiter's magnetosphere is imperfect, with the angular velocity decreasing with increasing distance from Jupiter, owing to the weakness of the atmosphere-magnetosphere coupling and the rapid injection of plasma from Io into the magnetosphere. Nevertheless, corotation has important effects on the magnetosphere, including the 10-hour spin modulation of energetic particles and magnetic fields in the magnetosphere and the spin-periodic ejection of energetic particles into interplanetary space. The centrifugal force of corotation is responsible, at least in part, for inflating the outer magnetosphere into a dipolar field geometry, and several authors have suggested that the corotational centrifugal force causes the magnetic field to open at some distance to allow the escape of accumulated plasma in the form of a 'planetary wind.' Pioneers 10 and 11 had discovered persistent modulations of the magnetic field and particle fluxes at Jupiter's 10-hour rotation period, both inside and outside the magnetosphere, as illustrated schematically in the cover figure A. The 'magnetic-disc model' attributes these 10-hour variations within the magnetosphere to the diurnal precession of Jupiter's magnetic axis about its spin axis, which causes a periodic wobble of the disc field configuration (cover figure B). The 'magnetic anomaly model' attributes the 10-hour variations both inside and outside the magnetospheres to the corotation of a longitudinal plasma asymmetry (cover figure C) that causes the planetary wind and related processes to vary with the spin period. The Pioneer trajectories lay almost entirely outside the range of latitudinal wobbling of the proposed disc (cover figure B), and the disc model would thus predict only one maximum and one minimum per 10-hour cycle, as would the anomaly model. The two models were thus indistinguishable on the basis of Pioneer data. The trajectories of both Voyager spacecraft lay within the latitude range of the hypothetical rigidly wobbling disc (cover figure D), where in the disc model would predict two maxima and two minima per rotation (cover figure E, solid line), while the anomaly model would still predict one (cover figure E, dashed line). Voyager data within 80 R_J are generally consistent with the disc model signature, while a number of observations (some of them noted below) appear to require the existence of a corotating anomaly as well.

V. M. Vasyliunas compared Voyager 1 and 2 plasma measurements obtained by the plasma science experiment (PLS) and by the low-energy charged-particle experiment (LECP). The departures from rigid corotation reported by the PLS are consistent with a predicted corotation lag caused by the inertial drag of plasma continuously injected by Io. The LECP results reported by S. M. Krimigis et al., on the other hand, indicate strict corotation to greater distances than would seem to be consistent with the PLS results, and there remains some controversy as to the degree to which corotation is enforced in the outer magnetosphere (see section entitled 'Outstanding Issues and Controversies,' below). R. L. McNutt reported from PLS measurements that departures from corotation become significant beyond the orbit of Io at 6 R_J and that the PLS results would be consistent with the 5% lag in the outer torus inferred by Kaiser from the narrow-band kilometric observations.

Vasyliunas also noted that the antisunward flow reported by the LECP experimenters in the distant magnetospheric tail was consistent with theoretical expectations based on the concept of a planetary wind (Figure 5). Apparently this wind consists primarily of heavy ions from the Io torus, although the composition of the wind was not measured directly.

R. P. Lepping reported Voyager observations of spin-periodic perturbations of the magnetic field in the magnetosheath (just outside the magnetosphere). These observations appear to support the basic premise of the magnetic anomaly model. A. W. Schardt presented an analysis of Voyager crossings of the magnetospheric current sheet (disc). His analysis indicated a reduced Alfvén wave propagation speed, and hence an enhanced plasma mass density, in the active sector as defined by the magnetic anomaly model. J. de Pater showed on analysis of high-frequency radio observations that suggests the existence of a rotating 'hot spot'—a localized excess concentration of relativistic synchrotron-radiating electrons near the planet—in roughly the same active sector as that defined by the magnetic anomaly model.

Particle Acceleration, Diffusion, and Loss

The classical mechanism for particle acceleration in planetary magnetospheres is the 'betatron' process whereby charged particles are transported inward into regions of higher magnetic field strength. If the transport occurs adiabatically with respect to the first and second adiabatic invariants, the particle's cyclotron energy increases in proportion to the increase of equatorial magnetic field strength. The process is then analogous to the adiabatic compression of an ideal gas. The inward transport may occur through randomly phased inward and outward motions of magnetic flux tubes ('radial diffusion') or through a systematic circulation ('convection') in which particles are transported inward on one half of the flow cycle and outward on the other half. Pioneer 10 and 11 observations had confirmed the importance of betatron acceleration through radial diffusion in Jupiter's magnetosphere, as well as the expected role of Io in accelerating particles to energies of several hundred kiloelectron volts. The Pioneer observations also, however, demonstrated the need for an additional, faster, and more potent mechanism to produce the several million electron volt particles observed in the outer magnetosphere (where the magnetic field is relatively weak), as well as the similar particles that are ejected into interplanetary space.

T. W. Hill reviewed recent theoretical mechanisms that focus on the problem of explaining the energetic particles (several million electron volts) observed in the outermost magnetosphere and in interplanetary space. One is a recirculation mechanism wherein particles are recycled through the betatron process by alternating cycles of adiabatic compression and nonadiabatic (rapid) expansion. The 'magnetic pumping' process also involves alternating cycles of adiabatic acceleration and nonadiabatic relaxation, but it utilizes the day-night variation of magnetic field strength along a corotational drift path rather than the radial gradient of field strength. Both of these processes are capable of producing million electron volt energies in the outer magnetosphere, but both are intrinsically slow processes that apparently cannot explain the high rate of ejection of energetic particles into interplanetary space and the rapid refilling of the outer magnetosphere.

A potentially powerful and rapid acceleration mechanism involves magnetic merging or field annihilation in the current sheet of the outer magnetosphere. This process provides, in principle, a means of rapidly tapping the energy stored in the highly stressed magnetic field configuration. The merging theory is not sufficiently developed to make quantitative predictions of the expected particle energy spectrum, but observation in Earth's magnetospheric tail suggest that the merging process is capable of producing the required high energies on the required short time scale. R. W. Fillius reviewed an important analysis of Pioneer observations by A. W. Schardt and colleagues, showing evidence of local acceleration of energetic particles in the outer-magnetospheric current sheet. The observed flow of energetic ions away from the current sheet apparently implies a total acceleration rate of the order of 10^{14} W and a relatively short particle lifetime of the order of the 10-hour Jovian rotation period. These observations can be taken as evidence for a current-sheet field annihilation process.

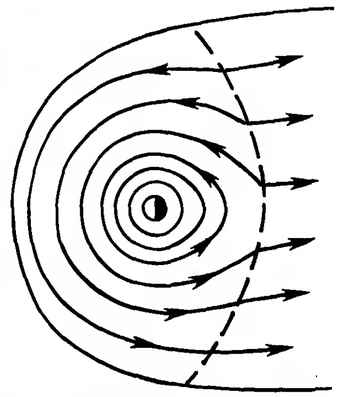

Fig. 5. Schematic illustration of the generation of a planetary wind on Jupiter's nightside (equatorial view, with the sun to the left). As illustrated here, plasma rotates on closed magnetic flux tubes throughout the dayside magnetosphere, but the outermost flux tubes are forced open to allow plasma escape in the dusk sector of the tail. Reconnection of these open flux tubes in the dawn sector of the tail produces the apparent divergence of the flow lines away from the reconnection region (dashed line), resulting in primarily rotational flow within the dashed line and tailward flow beyond the dashed line. As pointed out by V. M. Vasyliunas, this theoretical scenario is consistent with observations reported by the Voyager low-energy charged-particle experiments.

A. J. Dessler pointed out the existence of a theoretical upper limit to the rate at which energy can be drawn from the centrifugal potential field of corotation, this limit being proportional to the rate at which plasma is injected by Io into the magnetosphere. Using the largest values inferred for this plasma mass injection rate (~10^3 kg/s), the upper limit is dangerously close to the 10^{14} W that was mentioned earlier in reference to both the torus-associated aurorel emission and the current-sheet acceleration process.

Fillius and C. E. McIlwain noted that the possible role of large magnetic-field-aligned electric fields has been generally overlooked in theoretical attempts to explain the MeV electrons observed in the outer magnetosphere, although such fields are widely recognized as important in the acceleration of auroral electrons in the terrestrial magnetosphere. Differential rotation between different portions of a given field line can in principle produce megavolt potential drops along the magnetic field.

A. Hasegawa presented a theory of a 'ballooning instability,' wherein the centrifugal force of the plasma that streams along the sharply curved magnetic field lines which thread the current sheet forces the magnetic field to stretch to the breaking point. The instability is analogous in some respects to the classical Rayleigh-Taylor instability, with the centrifugal 'gravity field' directed outward. The instability may be instrumental in releasing the plasma/wind outflow and in establishing the highly stressed magnetic field configuration that is a prerequisite for the fast magnetic merging process described earlier.

M. Schulz discussed a synergistic interaction between two radiation modes that effect the loss of relativistic electrons in the innermost magnetosphere—a cyclotron instability, which tends to occur near the magnetic equator, and synchrotron emission, which tends to occur more at the high-latitude excursion of a particle bounce trajectory along a magnetic field line. Each radiation mechanism alters the particle velocity distribution in such a way as to enhance the other. The interplay between the two radiation mechanisms was thus aptly described by Schulz as a 'cyclotron-synchrotron maser.'

Outstanding Issues and Controversies

The first two points listed below were discussed at length in the final session of the conference; these discussions served to bring the issues into clearer focus but did not really resolve them. The remaining questions were identified or emphasized during the course of the conference as critically important issues to be resolved by future research.

There is an apparent discrepancy between plasma flow measurements reported by the two plasma experiments on each of the Voyager spacecraft. The two experiments cover different ranges of particles energies but should presumably give the same value for the components of plasma flow perpendicular to the magnetic field, and in particular, for the corotational component of flow. As was pointed out by Vasyliunas, there is not yet a clear, direct conflict between the two sets of measurements because there is no overlap between the regions of space within which the two experiments have reported flow measurements. However, the PLS has reported significant (up to 50%) departures from ideal corotation between 10 and 40 R_J distances, the degree of departure increasing with increasing distance, as expected theoretically, while the LECP has reported essentially rigid corotation between 40 and ~100 R_J. It is difficult to reconcile these two results theoretically, and a direct comparison of simultaneous results from the two instruments in the same region of space would be desirable in order to decide whether we have an experimental discrepancy on the one hand or a theoretical dilemma on the other.

It is important to establish whether the source of torus plasma is localized near Io or is distributed widely around Io's orbit. In the former case, the low intensity of UV emission observed from Io's vicinity would be hard to reconcile with the large plasma injection rates (≥10^3 kg/s) inferred from the optical observations, the intensity of the Io-associated Jovian aurora, and the observed corotation lag. In the latter case, the interesting problem would be to account theoretically for such a widely distributed source.

- How persistent are the reported local-time asymmetries in UV torus emissions and certain low-frequency radio emissions? Can these asymmetries be attributed to a latitude rather than a local-time variation? If the local-time variations are real, what do they tell us about the Io-Jupiter interaction?
- Is the rapid outward transport of torus plasma better described in terms of a systematic convection pattern or in terms of stochastic radial diffusion?
- What is the energy budget of the Io torus, and what are the sources and sinks of this energy?
- Is the Io-Jupiter current system better described as a steady state circuit closed by ohmic currents in Jupiter's ionosphere or as a system of Alfvén waves only weakly coupled to Jupiter's ionosphere?
- What is the nature of the interaction that produces the Ganymede wake?
- What are the precise locations of the various low-frequency radio sources? (The answer to this question would narrow the choices of relevant emission mechanisms.)
- What are the relative abundances of hot versus cold plasmas in the outer magnetosphere and the relative importance of their dynamical effects ('hot' and 'cold' being defined relative to the local corotation energy)?
- What are the relative roles of the disk model versus the magnetic anomaly model in producing 10-hour variations in the outer magnetosphere and beyond?
- What is the nature of the magnetosheath disturbances that are observed to occur with a 10-hour periodicity?
- What mechanism is primarily responsible for the rapid production of energetic particles in the outer magnetosphere and their ejection into interplanetary space?
- Does the planetary wind form just at, or significantly beyond, the distance at which the rotational energy density becomes comparable to the magnetic energy density? Does the planetary wind exhibit a 10-hour periodicity?
- Are there large-scale regions of magnetic-field-aligned electric fields associated with differential rotation? If so, what is their role in energetic particle acceleration?

This list is probably incomplete, but it serves to illustrate the kinds of questions we are learning to ask in this post-Voyager, pre-Galileo era of Jovian magnetospheric research.

Acknowledgments

I would like to thank all of the conference participants, and especially the session chairman (P. A. Cloutier, A. J. Dessler, M. L. Goldstein, D. M. Hunten, E. C. Stone), the overview speakers (R. A. Brown, T. D. Carr, R. W. Fillius, C. K. Goertz, D. A. Gurnett, T. W. Hill, G. L. Siscoe, V. M. Vasyliunas), and the program committee (a subset of the above lists) for their indispensable contributions to the success of the conference (and for their tolerance of this imperfect review). I would also like to extend special thanks to the Space Physics and Astronomy Department and its chairman, Alex Dessler, for their sponsorship and support, and to Umbelina Cantu, Georgette Burgess, Rachel Mesh, Tom Tascione, and Huey-Ching Yeh for their logistical support. The preparation of this review was supported in part by NSF grant ATM78-21767.

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Thomas W. Hill holds a B.A. in physics (1967) and a Ph.D. in space science (1973), both from Rice University. Following a NAS/NRC Resident Research Associateship at the NOAA Space Environment Laboratory, he served a 4-year appointment on the Rice faculty and is presently an associate research scientist in the Rice University Center for Space Physics. His research interests have included the magnetospheres of planets generally and of Earth and Jupiter specifically. He is a Fellow of the AGU, a 1980 recipient of the James B. Macelwane Award, and an associate editor of *JGR-Space Physics*.

News

R & D Funding in 1981

Although it is widely accepted that federal budgets will be cut during the next year, it is apparent now that R & D support will remain strong for FY 1981. The National Science Foundation's overall budget has been increased by 8% for FY 1981. NASA R & D has gained 7% on its budget. The Department of Commerce R & D budget has been increased by 6%. The huge increases are among the military and defense agencies, some amounting to as much as 37% (Air Force), with an average DOD R & D increase of 19%. The table lists the increases by agency.

The breakdown of the NSF budget for FY 1981 includes a 15% increase in funding for mathematical and physical sciences; 9% for earth, ocean, atmosphere, and astronomical sciences; 10% for Antarctic programs; and 7% for biological and social sciences. The Ocean Margin Drilling Program will increase in budget by 13%.

The NASA budget and future programs will be affected by some interesting twists in congressional dictation. The overall R & D budget will be up, but a large number of NASA programs will be subject to funding ceilings. The ceilings are to combat cost overruns (especially in the space shuttle). Further, NASA must now accept program and project review recommendations from the National Academies of Science and Engineering. In other words, no proposed changes in program will be approved by Congress unless sanctioned by an Academy panel. The implications of this congressional move are uncertain.

Federal Research and Development Appropriations for 1981

Agency	1980	1981	Change, %
Defense	13,412.1	18,018.7	18
Agriculture	588.8	620.4	10
NSF	991.8	1,076.1	8
NIH	3,429.4	3,686.4	8
EPA	237.8	253.5	7
Commerce	5,244.8	5,541.2	6
NASA	821.8	872.5	7
Energy	3,320.0	3,358.1	1

Amounts in millions of dollars.

This overall requests of the Administration were followed almost 100%. The biggest discrepancies between the Administration's request and Congress' approval were in the budgets of the Defense Department, 3% less than requested, and the Environmental Protection Agency, 6% less than requested; however, both had large increases.—*PMB* ⊠

Upcoming Communications Satellites

A new series of international and business communications satellites will be launched by 'workhorse' rocket systems, including updated Delta and Atlas/Centaur rockets, over the next few years. There is, of course, a 'long-shot' option that the space shuttle, as originally conceived, will be used to place the satellites in orbit, but no one is willing to bet right now that the shuttle will be functional and operational in

(News cont. on page 28)

EOS

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Cover. Schematic illustration of two models that have been proposed to explain 10-hour variations in Jupiter's magnetosphere. Modulations of particle flux are schematically illustrated in panel A. In the disc model (panel B), the flux maxima are associated with spacecraft encounters with the current sheet located in the magnetic equatorial plane. In the anomaly model (C), the maxima are associated with spacecraft encounters with a particular active longitude sector (shaded). The Voyager 1 and 2 trajectories encountered the magnetic equator twice per rotation (D), unlike the Pioneer 10 and 11 trajectories (B). Thus the disc model would predict two flux maxima per rotation for Voyager (solid line in E), whereas the anomaly model would still predict one maximum per rotation (dashed line in E). Voyager measurements are generally consistent with the disc model within 80 R_J, whereas a number of Voyager observations and Earth-based observations seem to require corotating anomaly effects as well.

(News cont. from page 27)

time. Instead, the U.S. will employ updated versions of 15-20-year-old rockets to launch a series of satellites with names like 'INTELSAT,' 'INSAT,' 'Palapa,' and 'SBS' into geosynchronous orbits.

Communication Satellites

INTELSAT V is the first of a new generation of international telecommunications satellites sponsored by the 105-nation International Telecommunications Satellite Organization (INTELSAT), headquartered in Washington, D.C. The satellite, which weighs 1,928 kg at launch, has almost double the communications capability of early satellites in the INTELSAT series. It is positioned in geosynchronous orbit over the Atlantic Ocean so as to provide communications between North America and Europe.

INTELSAT V satellite is built by the Ford Aerospace and Communications Corp., Palo Alto, Calif., using system components developed by firms in France, the United Kingdom, the Federal Republic of Germany, Japan, and Italy. It has a capacity of 12,000 voice circuits plus two television channels.

The Atlas Centaur (AC-54) launch vehicle placed the INTELSAT V into a highly elliptical orbit from 168 by 35,788 km. It is from this orbit, at apogee, that a solid-propellent rocket motor attached to the satellite will be fired to circularize the orbit at geosynchronous altitudes over the equator. At that altitude, because the speed of the satellite in orbit matches the rotational speed of the earth, the satellite will remain in position over one spot.

This INTELSAT V launch costs approximately $78.6 million, including $34 million for the satellite and $42 million for the Atlas Centaur and related launch services, which is reimbursable to NASA under the provisions of a launch services agreement signed in May 1980.

NASA Administrator, Robert A. Frosch, and Satish Dhawan, secretary of the Government of India's Department of Space, signed an agreement recently in Bangalore, India, calling for the launch of two Indian communications/meteorological satellites. The two satellites, Indian National Satellite (INSAT) 1A and 1B, operating in geosynchronous orbit, will provide India with point-to-point voice and television communications, community broadcasting, and weather data. The two satellites are being built by Ford Aerospace Corporation.

The agreement calls for the Department of Space to be responsible for satellite manufacture and checkout and integration of the spinning solid upper stage (SSUS), which will boost the satellites into elliptical transfer orbit from which they will be maneuvered into their geosynchronous operating orbits. NASA will provide all other launch-related services through the Kennedy Space Center, Fla.

Stanley I. Weiss, NASA associate administrator for space transportation operations, and Dr. Suryadi, director general of posts and telecommunications for the Republic of Indonesia, signed an agreement in Jakarta, calling for the launch by NASA of two Indonesian communications satellites by January 1984.

The two satellites, Palapa B-1 and B-2, operating in geosynchronous orbit, will provide voice, video, telephone, and high-speed data services to Indonesia and other member states of the Association of Southeast Asian Nations—the Philippines, Thailand, Malaysia, and Singapore.

The agreement calls for Indonesia to be responsible for satellite checkout and integration of the spinning solid upper stage, and NASA will provide all other launch-related services through the Kennedy Space Center, Fla.

The first of three satellites in an advanced commercial communications system being established by Satellite Business Systems, McLean, Va., called SBS-A (SBS-1 in orbit), is being launched on a Delta launch vehicle. This is the 153rd launch of a Delta. Over the past two decades the McDonnell Douglas-built launch vehicle has had a mission success rate of better than 90%.

The launch will mark the debut of a new solid-fuel payload assist module (PAM-D), which will provide an approximate 20% increase in payload capability on missions to geosynchronous orbit over a Delta TE-364-4 third stage. Developed with private funding by the McDonnell Douglas Astronautics Co., Huntington Beach, Calif., the payload assist module is the Delta version of the spinning solid upper stage designed for use in the space shuttle.

The SBS-A is a 550-kg satellite that will provide integrated, all-digital, interference-free transmission of telephone, computer, electronic mail, and video teleconferencing to SBS business and industrial clients. The service should be inaugurated early this year. The second satellite in the series is scheduled for launch on a Delta this year, and the third one will be launched from the space shuttle in late 1982. By 1983, SBS also plans to establish an intercity satellite telephone service that will connect up to 150 metropolitan calling areas.

SBS-A is a spin-stabilized satellite 218 cm in diameter, with a stowed height at launch of 282 cm. After deployment in its geosynchronous orbit at about 35,880 km above the earth, the telescoping solar panel cylinder will be extended and the communications antenna raised, giving the satellite an overall height of 860 cm. Each has a high-speed, all-digital 10-transponder system capable of relaying up to 480 million information bits of data per second, the equivalent of more than 10 million words. They are also the first U.S. domestic commercial communications satellites to use the higher, less congested 12/14 Gh (K-band) frequencies.

Once in orbit at 106°W over the equator—about due south of Santa Fe, N.M.—the satellite's antenna pattern will cover the continental United States, delivering higher power to metropolitan regions in the East, Midwest, and West Coast, where SBS customer communications traffic will be greatest. The payload assist module, being flown for the first time on Delta in place of the conventional third stage, is designed to inject the satellite into an elliptical transfer orbit ranging from a perigee, or low point, of 188 km to an apogee of 14,252 km (22,950 mi.). It is from this orbit, at the fourth apogee, that the SBS-A apogee kick motor is fired, which will place the satellite into its geosynchronous operating orbit.

The Launch Vehicles

Overall, Delta, in service since 1960, is 35.4 m tall and weighs about 192,099 kg at liftoff. The first stage is a long-tank derivative of the Thor vehicle, 22.5 m long and 2.4 m in diameter. Its main engine, burning RP-1 fuel and liquid oxygen, is rated at 920,777 N at sea level. It has a burn time of 3 min 43 s. First-stage thrust augmentation is provided by nine solid fuel strap-on motors that are 11.2 m long. Five of the motors are ignited at liftoff and four ignite after the first five burn out. Each motor, with a burn time of 57 s, provides an average of 379,298 N of thrust.

Delta's second stage, burning nitrogen tetroxide as the oxidizer and Aerozene-50 as the fuel, is 6.4 m long and 140 cm in diameter. It produces 43,592 N of thrust and burns for about 300 s. The second stage also contains the guidance system that generates steering commands for the first and second stages, as well as timing, staging, and engine restarts when needed.

The Atlas Centaur is Ness's standard launch vehicle for intermediate weight payloads. It is used for the launch of Earth-orbital, Earth-synchronous, and interplanetary missions. Centaur was the nation's first high-energy, liquid-hydrogen/liquid-oxygen-propelled rocket. Developed and launched under the direction of NASA's Lewis Research Center, it became operational in 1966 with the launch of Surveyor 1, the first U.S. spacecraft to soft-land on the moon's surface.

Since that time, both the Atlas booster and Centaur second stage have undergone many improvements. At present, the vehicle combination can place 4538 kg in low Earth orbit, 1926 kg in a geosynchronous transfer orbit, and 907 kg on an interplanetary trajectory.

The Atlas Centaur, standing approximately 39.9 m high, consists of an Atlas SLV-3D booster and Centaur D-1AR second stage. The Atlas booster develops 1920 kN of thrust at liftoff, using two 822,920-N thrust booster engines, one 266,890-N thrust sustainer engine, and two vernier engines that develop 2890-N thrust each. The two RL-10 engines on Centaur produce a total of 133,450-N thrust. Both the Atlas and the Centaur are 3 m in diameter.

Until early 1974, Centaur was used exclusively in combination with the Atlas booster. It was subsequently used with a Titan III booster to launch heavier payloads into Earth orbit and interplanetary trajectories.

The Atlas and the Centaur vehicles have been updated over the years. Thrust of the Atlas engines has been increased about 222,400 N since their first use in the space program in the early 1960's.

The Centaur has an integrated electronic system that performs major role in checking itself and other vehicle systems before launch and also maintains control of major events after liftoff. The system handles navigation and guidance tasks, controls, pressurization and venting, propellent management, telemetry formats and transmission, and inflight vehicle events.

The Atlas and Centaur stages of Atlas Centaur 54 arrived at Cape Canaveral Air Force Station August 6, 1980. The Atlas was erected on Pad B of Launch Complex 36 on August 12; the Centaur was erected on August 14. A terminal countdown demonstration test was conducted October 3 to verify the integrity of the vehicle-to-ground systems in an environment that duplicates launch conditions.—*PMB* ✉

1981 Expendable Launch Vehicle Schedule

Date	Mission	Launch Vehicle	Launch Site	Sponsor and Description
February	COMSTAR-D	Atlas Centaur	ESMC*	Comsat General Corp.—communications—reimbursable
March	INTELSAT V-B	Atlas Centaur	ESMC	Intelsat—communications—reimbursable
March	GOES-E	Delta	ESMC	NOAA—weather—reimbursable
April	Navy 20 (Nova 1)	Scout	WSMC†	DOD—transit—reimbursable
April	SBS-B	Delta	ESMC	Satellite Business Systems—communications—reimbursable
May	NOAA-C	Atlas-F	WSMC	NOAA—weather—reimbursable
June	INTELSAT V-C	Atlas Centaur	ESMC	INTELSAT—communications—reimbursable
June	RCA-D	Delta	ESMC	Radio Corporation of America—communications—reimbursable
June	FLTSATCOM-E	Atlas Centaur	ESMC	DOD—communications—reimbursable
July	Dynamic Explorer	Delta	ESMC	NASA—scientific
September	Navy 22 (Nova 2)	Scout	WSMC	DOD—transit—reimbursable
September	INTELSAT V-D	Atlas Centaur	ESMC	INTELSAT—communications—reimbursable
September	Solar Mesospheric Explorer	Delta	WSMC	NASA—scientific
October	RCA-C1	Delta	ESMC	Radio Corporation of America—communications—reimbursable
December	INTELSAT V-E	Atlas Centaur	ESMC	INTELSAT—communications—reimbursable

*Eastern Space and Missile Center, Cape Canaveral, Fla.
†Western Space and Missile Center, Vandenberg Air Force Base, Calif.

Environmental Pollution, Chromosomes, and Health

In mid-May, 1980, President Carter declared a state of emergency at the Love Canal area, near Niagara Falls, New York. The reason for this was for the U.S. to underwrite the relocation costs ($3-5 million) of some 2500 residents who, according to a report by the EPA (Environmental Protection Agency) may have suffered damaged chromosomes. These injuries were apparently caused by contact with toxic wastes that had been dumped in the area in the years prior to development for housing.

That the toxic compounds exist in the Love Canal and Niagara Falls subsurface zones, including public water supplies, appears to be established fact. That the residents of the Love Canal area suffered chromosomal damage may be established fact as well. Whether or not these two findings can be linked to ill health of the residents is another matter. Recently, the EPA report has been described as having 'close to zero scientific significance,' and has been 'discredited' (*Science*, *208*, 123e, 1980). The reasons for this disparity go beyond differences of opinion, beyond possible inadequacies of the EPA study, and even beyond problems that probably will arise from future studies, including those now in the planning stages. The problem is that even if victims have easily recognizable injuries from toxic substances (injury that apparently has not occurred to Love Canal residents), medical science usually cannot show a causal relationship. Even chromosomal damage is, at best, difficult to interpret. In ideal studies of significant populations and control groups, the association of toxic chemical to chromosome damage and to cancer and birth defects is indirect and, up to now, has been shown to have little or no significance to an individual member of the exposed population.

Geophysicists concerned with groundwater resources and chemical pollution are becoming increasingly aware of the extent of such pollution caused by dumping of wastes. By the same token, residents of areas known to be polluted are becoming more concerned, and in some cases terrified. The residents of the Love Canal area have suffered, at least financially and psychologically, and the government has concluded that they deserve recompense. But, what of the real question of medical effects: cancer, miscarriages, birth defects, seizures, etc.? At this time, it would appear that the geoscientist concerned with pollution will have to proceed with studies, taking it on faith that uncontrolled disposal of toxic chemicals must cease.

The recent signing of the 'superfund' legislation by President Carter will clear the way for release of $1.6 billion for cleaning up sites that have been used as dumps of hazardous wastes. The residents of polluted or contaminated areas may find little salve for their injured emotional state. No doubt the long-term results of studies of the Love Canal dump site will be very beneficial, although perhaps not as direct as might be desired. In a short article on chromosome damage, G. B. Kolata (*Science*, *208*, 1240, 1980) points out that while such damage can be an important result of exposure to toxic chemicals, some damage occurs naturally from numerous nontoxic causes. In fact, the normal number of cancer cases, birth defects (11% of all children born), and spontaneous abortions (as high as 50%) is so high that it is usually difficult or impossible to show significant increases, particularly in populations the size of most communities.

It is interesting to note that studies of the survivors of nuclear bombings of Hiroshima and Nagasaki showed that correlation between increases of cancer incidence and the degree of radiation exposure could be made only on a population basis. Individuals who had received significant radiation had recognizable chromosomal damage, but still, according to Kolata, those individuals with the greatest amount of damage were not necessarily those who got cancer. No increases in birth defects or miscarriages were observed statistically.

The assessment of chromosome damage is as much an art as a science. White blood cells must be carefully cultured, then stained and examined under the microscope. The 46 chromosomes in a human cell can be individually identified by their characteristic shapes and size. If there is damage, it often appears as breaks and deletions, or as rings, which are formed from chromosome fragments. Cells with damaged chromosomes usually die or repair the damage.

Although the chromosomes are the carriers of genes, almost never can specific chromosomal aberrations be associated with specific birth defects or cancer. One exception is Down's syndrome, in which individuals inherit an extra chromosome 21, and this extra chromosome shows up in all their cells. But most genetic defects and most DNA damage that may lead to cancer involve subtle microscopic changes in DNA and quite often do not lead to physical changes in the chromosomes. There is only indirect evidence associating chromosome damage with birth defects and cancer. (*Science*, op.cit).—*PMB* ✉

Thermosphere Circulation Modeled

When solar storms force the earth's auroras to lower latitudes, winds in the thermosphere reverse direction and are whipped up to velocities of 2250 km/h. A computer model has now been developed that will describe the circulation of the thermosphere—a 400-km blanket enveloping the earth, with its bottom boundary at an altitude of 80 km—and its interaction with the auroras.

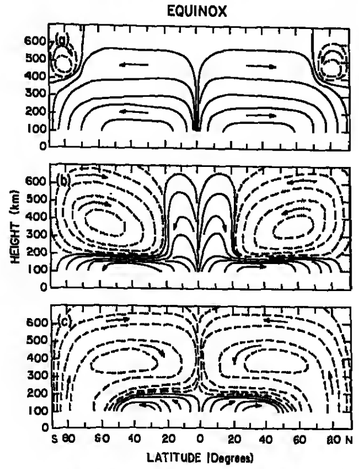
Raymond G. Roble, of the National Center for Atmospheric Research, explained at the AGU Fall Meeting that the thermospheric model might be useful to predict variations in storm time and atmospheric drag on some earth satellites. If the thermosphere's dynamics are better understood, he reasoned, more accurate predictions of a satellite's orbital decay can be made. The model may also help to predict the effects of communications equipment and magnetic forces on power grids.

Developed by Roble, E. Cicely Ridley, and Robert E. Dickinson, the model is a set of meteorological equations adapted from the NCAR model of general circulation in the lower atmosphere. The model is constructed as a global grid of more than 60,000 points at 24 altitudes throughout the thermosphere. At each point, the equations calculate the dynamic relationships between temperature, pressure, winds, and other variables. Circulation patterns are computed by simulating progression of time.

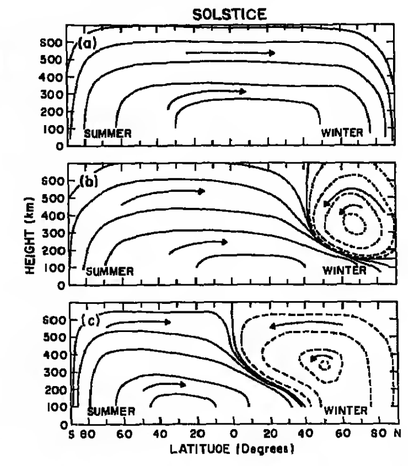
The model incorporates a geomagnetic pole that tilts away from the geographic pole. Because auroras are centered around the geomagnetic poles, the tilt imparts a wobble to the daily circulation of the thermosphere in the auroral zones.

The thermosphere is heated continuously by ultraviolet radiation from the sun. The region's basic circulation moves from the hot daylight portions to the cool nightside and back, with winds blowing several hundred kilometers per hour. The mean circulation is from the equatorial region toward the poles.

Sporadic auroral activity produces heat in the polar regions of the thermosphere, setting up an opposing circulation, for example, from the polar regions toward the equator. This happens on a small to medium scale several times a day. During major geomagnetic storms, the aurora-induced circulation overwhelms its ultraviolet counterpart and reverses almost the entire flow in the thermosphere. Winds in this powerful counterflow have been measured over 1600 km/h, and in one case over 2250 km/h. ✉



Schematic diagram of the zonal mean meridional circulation in the earth's thermosphere during equinox for various levels of auroral activity: (a) extremely quiet geomagnetic activity, (b) average activity, and (c) geomagnetic substorm. [Source: NCAR]



Schematic diagram of the zonal meridional circulation of the earth's thermosphere during solstice for various levels of auroral activity: (a) extremely quiet geomagnetic activity, (b) average activity, and (c) geomagnetic substorm. [Source: NCAR]

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Columbia, Missouri 65211

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Ocean Dynamicist. An academic position (tenure-earning track) for an ocean dynamicist is presently available in the Department of Oceanography, Naval Postgraduate School (NAVPGSCOL). Present or ultimate research interest in area of naval oceanographic concern is desirable. Such areas include: ocean circulation modeling, especially prognostication on the oceanic synoptic scale; surface and internal gravity wave dynamics; synoptic analysis of oceanic data; and acoustical oceanography. The candidate should be willing and able to teach a variety of graduate courses in physical oceanography and related topics. The NAVPGSCOL has excellent computer, data archival, library, and research vessel facilities. The Department of Oceanography has close relations with the Fleet Numerical Oceanography Center, Naval Environmental Prediction Facility, and the Naval Laboratories. The department has a faculty of fifteen and a student body of 80 to 100. The overall emphasis is ocean prediction with present faculty and student research in coastal ocean, polar ocean, and air-sea interaction processes. The academic and research programs are conducted in close collaboration with the Departments of Meteorology and Physics. Salary will be determined by qualifications of the successful candidate. By January 1 if possible, send a curriculum vitae, the names and addresses of three references, and a statement of research and instructional interests to: Faculty Search Committee, Department of Oceanography, Naval Postgraduate School, Monterey, CA 93940. Visits by top candidates will be scheduled soon after. A decision will be attempted by March 1, and the position should be occupied by about June 1, 1981.

The Naval Postgraduate School is an equal opportunity employer.

Faculty Position/California Institute of Technology. The Division of Geological and Planetary Sciences, California Institute of Technology, seeks outstanding candidates for a position in geophysics with primary emphasis on young people interested in observational seismology. Opportunities include availability of arrays and large seismic data sets, as well as challenging regional tectonic problems. Appointment is sought preferably at the assistant professor level.

Please contact B. Kamb, Chairman, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, giving resumé, bibliography, and research interests.

An equal opportunity employer.

Exploration Geophysics/University of Oklahoma. As part of a 5-year plan of development and expansion, the School of Geology and Geophysics is looking for a person to form the nucleus of an exploration geophysics group. A Ph.D. in geophysics is required, and preference will be given to someone whose teaching and research interests are in the acquisition, processing, and/or interpretation of seismic data. Present equipment includes a truck-mounted 'thumper' energy source, capable of penetrating a kilometer or more of rock; a portable, 12-channel seismic recording system; gravimeters; magnetometers; an electrical resistivity unit; in-house mini computers; and terminals to the University's IBM 370 system. A geophysical observatory supports research in solid earth geophysics, and the exploration geophysicist would work closely with the tectonics-solid earth geophysics group.

Applications are due February 15, 1981. Salary is competitive with industrial standards. Inquiries and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma does not discriminate on the basis of race or sex and is an equal opportunity employer.

Hydrologist. Sigma Data Computing Corp.'s Division of Information and Scientific Applications invites applications from hydrologists qualified to participate in an environmental modeling/chemical fate assessment team effort.

The applicant will evaluate terrestrial and groundwater models and their data requirements to form a comprehensive multimedia modeling library system for assessment of toxic chemicals. The applicant will also provide recommendations for modification of existing model algorithms and R&D for anticipated continuing model development.

An M.S. degree or equivalent experience is a minimum requirement. Programming experience in FORTRAN and use or development of water quality models is desirable but not essential.

Salary is commensurate with qualifications.
Please submit resume and references to:
Roger Long
Sigma Data Computing Corp.
2021 K Street, NW
Suite 207
Washington, D.C. 20006

Research on Lunar Samples. Applicants for this postdoctoral research position should have experience in at least one of the areas: lunar-sample research, meteorite research, or neutron-activation analysis. Salary about $16,000 per annum. J. T. Wasson, Institute of Geophysics & Planetary Physics, University of California, Los Angeles, California 90024.

UCLA is an affirmative-action/equal-opportunity employer.

Drexel University/Atmospheric Scientist. Three tenure track faculty positions are anticipated starting fall 1981. Applications are solicited from Ph.D.s with independent research experience in one of the following areas of atmospheric science: general circulation; climate dynamics with application in satellite meteorology; atmospheric optics, experimental or theoretical with emphasis in mesoscale probing; boundary layer turbulence modeling and atmospheric chemistry modeling. Rank and salary commensurate with experience. Send resume and references to Dr. William W. Eidson, Head, Department of Physics and Atmospheric Science, Drexel University, Philadelphia, PA 18104.

An equal opportunity/affirmative action employer.

Stable Isotope Geochemistry/University of Saskatchewan. The Department of Geological Sciences has a vacant tenure track position at the assistant professor level for a stable isotope geochemist. Applicants should hold (or be about to receive) the Ph.D. degree, be qualified to instruct undergraduates in general geology and undergraduates and post-graduates in geochemistry and petrology, be prepared to pursue a vigorous research program, and to assume control of a geochemistry research laboratory with Micromass 902 Double Collecting Mass Spectrometer. Letter of application, with curriculum vitae including the names of at least three referees, should be sent to W. O. E. Caldwell, Head, Department of Geological Sciences, University of Saskatchewan, Saskatoon, Canada, S7N 0W0.

Sedimentary Petrologist. The Geology Department at the University of Vermont is seeking a sedimentary petrologist for a tenure track position at the assistant professor level. Research and teaching specializations should be in clastic sedimentary petrology with potential ancillary interests in petroleum geology, geomorphology, and hydrology. It is expected that the successful candidate will establish a field oriented research program which includes supervision of graduate (M.S.) and undergraduate students. A Ph.D. is required and teaching experience is highly desirable. The Geology Department at the University of Vermont is a seven member department having an M.S. program and a definite commitment to excellence in undergraduate education. Applications will be accepted until April 1, 1981.

Candidates should send a resume and arrange for three letters of reference to be sent to

John C. Drake
Acting Chairman
Department of Geology
University of Vermont
Burlington, Vermont 05405

The University of Vermont is an equal opportunity-affirmative action employer.

Seismologist. The University of Nevada Seismological Laboratory invites applications for the position of lecturer-research seismologist. Candidates with interest in seismological research related to earthquake hazard, earthquake prediction, theoretical source mechanisms, and/or seismic signal characteristics at regional distances are encouraged to apply. Teaching duties will consist of one undergraduate or graduate course per semester plus participation in graduate seminars.

Ph.D. degree in geophysics with at least three years research experience in earthquake seismology is appropriate for this position. Salary up to $30,000 for twelve-month contract, depending on background and experience. Position two thirds supported by state, one third by grants and contracts. Available on or after 1 May 1981.

Deadline 1 March 1981.

Candidates should send a letter of application, list of publications, statement of teaching and research interests, transcripts and names of five references to Alan Ryall, Director, Seismological Laboratory, University of Nevada, Reno NV 89557.

AA/EOE.

Postdoctoral Research Associate. Oceanography Department of the Naval Postgraduate School seeks recent graduate to study the hydrodynamics through numerical ocean modeling of the physical oceanographic processes active in the vicinity of the arctic ice edge off Alaska. Problem areas include the effects of the complex bathymetry on the circulation and frontal formation, the dynamics associated with interleaving of water masses at the ice edge, and the mechanisms involved in ice retreat. Research will be performed in the context of an observational program which has acquired data and developed insights over the course of several years.

Position is available March 1981 and is renewable annually. Salary depends upon qualifications. Send resume and the names and addresses of three references to Faculty Search Committee, Dept. of Oceanography, Naval Postgraduate School, Monterey, CA 93940.

Equal opportunity, affirmative action employer.

Staff Scientists/Ocean Margin Drilling Program. Joint Oceanographic Institutions, Inc. (JOI, Inc.) has immediate openings for two staff scientists to fill the positions of:

- Field Programs Coordinator
- Downhole Measurements Coordinator

in its Ocean Margin Drilling (OMD) Science Programs Office. Individuals filling each of these positions will report to the OMD Chief Scientist. They will be required to provide staff support to advisory committees in their area of concern, and will be responsible for implementing programs recommended by the OMD Science Advisory Committee, including oversight of the performance of individuals or groups under contract to JOI. Both positions require a Ph.D. in an appropriate area of earth science and appropriate experience. The OMDP is funded for FY '81. Initial appointment will be for a period of two years with the second year contingent upon the availability of funds. The positions may be filled on a rotating basis. Salary will be competitive. Send resume, statement of interest, and the names of three referees to Thomas A. Davies, Chief Scientist, Ocean Margin Drilling Program, Joint Oceanographic Institutions, Inc., 2600 Virginia Ave., NW, Suite 510, Washington, DC 20037. The deadline for applications is February 20, 1981, or as soon thereafter as suitable candidates are found.

Director/School of Meteorology. The University of Oklahoma invites nominations and applications for the post of director of the School of Meteorology effective for the 1981 fall semester. The school offers programs of study leading to B.S., M.S., and Ph.D. degrees in areas ranging from traditional atmospheric sciences to application-oriented climatology. Many of those programs have developed close, synergistic relationships with the activities of the National Severe Storms Laboratory, the Oklahoma Climatological Survey, and the OU-NOAA Cooperative Institute for Mesoscale Meteorological Studies, relationships that offer attractive opportunities for innovative multidisciplinary and interinstitutional programs.

Applicants should have a Ph.D. in meteorology or a closely related field and several years of relevant experience or equivalent qualifications, and should qualify for regular academic appointment.

The University of Oklahoma offers a comprehensive meteorology program comprising about 120 undergraduates, 60 graduate students, 8 faculty members, and several research associates. The program has been highly productive as measured by its sponsored research activities and the success of its graduates. The director is expected to provide leadership that will sustain and improve the quality and character of meteorology at the University of Oklahoma as well as to contribute to the teaching and research programs of the school.

Nominations and applications should be sent to Wm. R. Upthegrove, Chairman, Meteorology Directorship Search Committee, 107 Carson Engineering Center, University of Oklahoma, Norman, Oklahoma, 73019.

Applications should include a resume, a list of publications, and names of at least three professional references. In addition, candidates are encouraged to submit supplemental statements of their professional goals and their impressions of the directions and goals for atmospheric sciences in the 1980's.

Initial screening will begin February 23, 1981; however, applications will be accepted and recruiting continued until the position is filled.

The University of Oklahoma is an equal opportunity/affirmative action employer.

Hydrogeologist. The State University of New York at Binghamton invites applications for a permanent position in groundwater hydrology, starting fall 1981. It is desirable that applicant have teaching and research interests in one or more of the following: groundwater hydrology, modeling, flow through porous media, and environmental hydrogeology. However, applicants with interests in other areas will be considered.

Teaching responsibilities will include both undergraduate and graduate courses. The opportunity exists to initiate courses at all levels, but development of one lower-level undergraduate course is essential. Research facilities include: electron microprobe, scanning electron microscope, X-ray diffractometers, atomic absorption and transmission spectrophotometers, and access to a large central computer as well as minicomputers in department. Appointment is planned as assistant professor, but not necessarily at beginning level. Salary is negotiable, but will be at competitive academic level.

Applicants should submit resumé and arrange for three letters of recommendation to be sent to James E. Sorauf, Chairman, Department of Geological Sciences, State University of New York at Binghamton, Binghamton, NY 13901.

State University of New York at Binghamton is an affirmative action/equal opportunity employer.

Geochemistry/Brittle Deformation, University of New Brunswick. The Department of Geology has a tenure track position available from July 1, 1981 at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students.

Applications will be accepted in the following fields: geochemistry of ore bodies, exploration, environmental or soil geochemistry, brittle deformation, rock mechanics or site engineering.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Structural Geologist/University of California, Santa Barbara. Applications are invited for a tenure track appointment in structural geology to be filled during 1981-1982, subject to availability of funds. Rank dependent upon qualifications and experience, but preference will be given to the assistant professor level. Successful candidates must have Ph.D. degree and strong desire and commitment to teach and direct MA, Ph.D., and undergraduate students in both structural and field geology. He/she will be expected to develop a strong research program and obtain outside funding for its support. Additional duties may include teaching physical geology and summer field geology.

Please send resume and evidence of teaching and research proficiency, by March 31, 1981, and arrange for early submission of four letters of recommendation to Dr. Arthur G. Sylvester, Chairman, Department of Geological Sciences, University of California, Santa Barbara, CA 93106. (805) 961-3156.

The University of California is an affirmative action/equal opportunity employer.

Staff Scientist. Staff Scientist to conduct research in satellite data analysis to understand environmental effects, in particular, to analyze operational satellite data to examine the composition of the atmosphere and its temperature variations, using IBM 360/195, CDC 6600, and CDC Cyber 175 computers. Require Ph.D. in physics or atmospheric sciences with good knowledge of FORTRAN and JCL computer languages, and background in spectroscopy and computer simulation. Minimum one year background in research.

Send resumes to Rodger Smith, Manager of Staffing, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, Maryland 20840.

An equal opportunity employer.

Meteorologists and Hydrologists/Saudi Arabia. The School of Renewable Natural Resources, University of Arizona, invites applicants for assignment as faculty members to the Institute of Meteorology and Arid Land Studies, King Abdulaziz University, Jeddah, Saudi Arabia. One year, renewable positions in meteorology and hydrology are available.

1. Ph.D. in meteorology with experience in undergraduate teaching and research. Curriculum includes courses in meteorological instruments and methods of observation, dynamic meteorology, synoptic meteorology, physical meteorology, and climatology.
2. M.S. in meteorology with practical experience in meteorologic operations and undergraduate teaching. Knowledge of WMO procedures.
3. Ph.D. in a hydrologic science or engineering with experience in undergraduate teaching and in research. Major emphasis will be in the areas of surface and groundwater development, water management in an arid environment and in evaluating the hydrologic effects of development.

Description: The project is funded by the Saudi Arabian government through the U.S.-Saudi Arabian Joint Commission on Economic Cooperation. Administration and logistic support is provided by the U.S. Treasury Department, while the program's implementation is by a contract with the Consortium for International Development. The goal of the project is to undertake technical cooperation to develop educational programs for meteorology, hydrology, arid land studies and environmental protection.

Salaries and allowances: Highly competitive with 25% overseas adjustment, housing, car and other allowances.

Availability: February 1, 1981, or soon thereafter for spring semester; September 20, 1981, for fall semester. Initial appointment of one year or more contingent on performance.

Closing date: January 15, 1981 for spring semester; February 15 for fall semester.

Application: The application should include the following: (a) a letter detailing principal qualifications and interests, (b) a curriculum vita, (c) name, address and telephone numbers of three references. Send to Martin M. Fogel, Director, CID/King Abdulaziz University Project, 317A Anthropology Building, University of Arizona, Tucson, AZ 85721, Telephone (602) 626-5344/2869.

EEO/AA employer.

Program Manager/Meteorology. Oceanographic Services, Inc., is seeking qualified applicants for the position of program manager for meteorological studies. Applicants should have an M.S. or Ph.D. in meteorology or atmospheric sciences, plus experience in the field. A broad general knowledge of air pollution, and an understanding of the air pollution regulatory environment, is helpful. Interested persons should send resume, references, and salary history to R. C. Senka, Oceanographic Services, Inc., 25 Castilian Drive, Goleta, CA 93117.

Remote Sensing/Ocean Engineering or Oceanography Faculty Position. Applications are solicited for two permanent nine-month positions involving both research and graduate and undergraduate teaching. Ability to initiate funded research is desirable. Send resume, brief statement of research areas, and the names of three references to F. W. Merrill, Search Committee, Department of Oceanography and Ocean Engineering, Melbourne, FL 32901.

Equal Opportunity Employer.

Research Physicist. Ph.D. and two years experience with ionospheric research related to communications properties or closely related area. Initial salary is $21,000/year for 40-hour week. Interested applicants with these qualifications should call Mr. Siosce at (301) 262-4400.

Graduate Assistantships/Physics and Astronomy. Graduate research assistantships and teaching assistantships in the Department of Physics and Astronomy of the University of Iowa are available to well-qualified students. The department has vigorous research programs in space physics, plasma physics, acoustics, astronomy, astrophysics, atomic physics, elementary particle physics, laser physics, nuclear physics, and solid state physics. Assistantships can begin in June, August, or January. Please address your inquiry to Department of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242.

Institute of Space and Atmospheric Studies/University of Saskatchewan. Applications are invited for postdoctoral research positions in auroral physics and atmospheric dynamics. Term is one year renewable. Experimental ability or experience with optical or radio techniques is desirable. Work may involve rocket, balloon or observatory measurements and their interpretation. Send resume, references and research interests to: D. J. McEwen, Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada S7N 0W0.

Faculty Position. The Department of Geology of the University of New Mexico seeks applicants for a position in clay mineralogy, low-temperature geochemistry, carbonate petrology, or economic geology. The appointment may be at the assistant, associate or full professor level contingent on approval of funding from the university. The individual must be strongly committed to teaching at both the undergraduate and graduate levels. In addition, he or she will be expected to develop a vigorous research program in his or her field of specialty and will be expected to supervise graduate students at the M.S. and Ph.D. levels. The closing date for application is April 15, 1981. Applicants should send a résumé, undergraduate and graduate transcripts, three letters of reference, and a brief discussion of research interests to Rodney C. Ewing, Chairman, Department of Geology, University of New Mexico, 87131.

The University of New Mexico is an equal opportunity/affirmative action employer.

Associate Director/Marine Science Institute. The University of Texas at Austin seeks to fill the open position of associate director of the Marine Science Institute. The associate director is responsible for research and intellectual leadership of the Institute's Galveston Geophysics Laboratory. The position carries the line responsibility of senior administrator for the Galveston Geophysics Laboratory. Duties include research planning and management, fiscal monitoring and budgeting, personnel review and assignment, coordination of scientific programs and shop operations, administrative supervision, liaison with industrial and agency sponsors, representation and other directorship duties.

The Galveston Geophysics Laboratory maintains modern computing facilities, research laboratories, and two deep-ocean research vessels, the R/V Fred Moore and the R/V Ida Green. Research at Galveston includes programs in marine geophysics, marine geology, solid earth geophysics, earthquake and extra-terrestrial seismology, and instrument systems design, both basic and applied.

Applicants are asked to send the following:

(1) Vita—including list of publications.
(2) Brief statement on current research and support.
(3) Brief statement on administrative experience.
(4) Brief statement on teaching experience.
(5) Names of six persons who may be contacted for personal and professional recommendations.

A letter of application and the above requested information should be sent to:

Dr. J. Robert Moore, Director
Marine Science Institute
University of Texas
P.O. Box 7999, University Station
Austin, Texas 78712

Salary based on qualifications. Ph.D. required. The successful candidate will also be considered for tenure appointment in the Department of Marine Studies. Position to be filled as soon as possible. Early application advised. Position located in Galveston, Texas.

An equal opportunity/affirmative action employer.

Faculty Positions: Astronomy/Space Physics. The Department of Astronomy of Boston University invites applications for one or two tenure track faculty positions opening September 1981. Emphasis will be placed on active research experience as well as interest in graduate and undergraduate teaching. We are considering good candidates from any field of astronomy or space physics. Applicants should send resumes and the names of three references to M. D. Papagiannis, Department of Astronomy, Boston University, Boston, MA 02215.

Boston University is an equal opportunity employer.

Virginia Polytechnic Institute and State University. Igneous Petrology and Geochemistry/Research Associate. Origin and tectonic significance of granitic rocks. Project involves petrography, analytic chemistry, mineral chemistry, isotopic studies, and field mapping. Send résumés to:

D. R. Wones, Chairman
Department of Geological Sciences
Virginia Poly. Inst. and St. Univ.
Blacksburg, VA 24061

The University is an equal opportunity/affirmative action employer.

Structural Geologist. The Department of Geosciences at Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses, and pursue an active research program. Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and engineering geology and has a close working relationship with the geotechnical group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for application is April 1, 1981. Applicants should send a resume, the names, addresses, and telephone numbers of three referees, and a brief statement of research interests to R. H. McCallister, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

Synoptic/Dynamic Meteorology.

Description: The Geophysical Institute and Division of Geosciences, University of Alaska, invite applications from qualified scientists for a full-time (12 month) faculty position at the Assistant or Associate Professor level. The successful candidate will be expected to prepare and submit research proposals to external agencies and to work cooperatively with ongoing research programs. He/she will be also expected to teach occasional courses in synoptic/dynamic meteorology at the upper division and graduate levels.

Qualifications: Ph.D. in meteorology. Research experience in advanced analysis and diagnostic studies of global-scale meteorological processes is essential, preferably over the full height of the atmosphere (0-100 km). Preference will be given to applicants who can utilize their expertise in synoptic/dynamic meteorology to synthesize the results of various ongoing research projects in mesoscale and large-scale meteorology, cloud physics, radiation, aeronomy, and space physics into a better understanding of the large-scale meteorology of the North Pacific and polar regions. Teaching experience at the undergraduate and graduate levels is desirable.

Salary: Upward to $34,800 (Asst. Prof.) or $43,300 (Assoc. Prof.) per year, dependent upon qualifications and experience.

Applications: For further information, including recent annual research report, write to Director, Geophysical Institute, University of Alaska, Fairbanks, AK 99701. Closing date for applications is February 28, 1981.

The University of Alaska is an equal opportunity/affirmative action employer.

Meetings

Geophysical Fluid Dynamics

The symposium on geophysical fluid dynamics, part of the European Geophysical Society's 8th meeting in Uppsala, Sweden, August 24-29, will include special sessions on the physics of lakes and fjords.

The special sessions will include discussion of circulation and the effects of the earth's rotation; seasonal and climatic effects; stratification; heat, momentum, and gas transfers; surface and internal waves; tides; effects of islands, bays, and sills; effects of river or melt water inflow; ice; heat flow; and sedimentation.

Potential contributors should notify the convenors by April 30. The convenors are J-E. Weber, Institute of Geophysics, University of Oslo, P.O. Box 1022, Blindern, Oslo 3, Norway, and S. A. Thorpe, Institute of Oceanographic Sciences, Brook Road, Wormley, Godalming, Surrey, England GU8 5UB.

Deadline for receipt of abstracts is June 1. Abstracts should be sent to K. M. Storetvedt, Program Committee Chairman, Universitetet i Bergen, Geofysisk Institutt, Adv. C, Allegt. 70, N-5014 Bergen-Universitetet, Norway. ■

Environmental Systems Conference

A call for papers has been issued for a working conference entitled Environmental System Analysis and Management. Sponsored by the International Federation for Information Processing (IFIP), the conference is scheduled for September 28-30 at the IBM Scientific Center in Rome.

The conference is intended to provide an international forum for a broad interdisciplinary exchange of views among scientists who work in environmental science. Main areas of interest include water resources planning and management; air, water, and soil pollution; natural resources management; urban and regional planning; food and agriculture; energy and environment; environmental data bases; information systems for environmental problems; and environmental systems telemetering.

Abstracts of about 1000 words should be submitted in triplicate by March 15. Full papers will be required by September 30. Address abstracts and other conference correspondence to S. Rinaldi, Centro Teoria dei Sistemi, CNR, Politecnico, Via Ponzio, 34/5, 20133 Milano, Italy; telex 333487 or telephone 02-2367241. ■

Mexican Geophysical Meeting

Abstract deadline for the 1981 meeting of the Union Geofísica Mexicana is March 30, 1981. The meeting is scheduled for May 6-9 in Manzanillo, State of Colima, on the Pacific coast of Mexico.

Sessions will be held on the physics and chemistry of the earth's interior, exploration geophysics, atmospheric sciences, physical oceanography, and space and planetary physics.

Registration for the meeting is $33 for UGM members, $11 for students, and $65 for nonmembers. Nonmembers wishing to join UGM may apply for membership and should include the annual fee ($30 for active membership, $30 for associate membership, or $9 for student membership).

For more information about the meeting or about joining the Union, write to Union Geofísica Mexicana, Comité Reunión 1981, Instituto de Geofísica, UNAM Cd. Universitaria, Mexico 20, D.F. ■

GAP

Aeronomy

0310 Absorption and scattering of radiation (particles or waves)
THE COLLISION INDUCED-LINE WIDTHS OF CHLORINE AND BROMINE MONO-OXIDE PERTURBED BY NITROGEN
S. Dutta-Roy and S. C. Mehrotra (Chemical Physics Group, Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay 400 005, INDIA)

Using the semiclassical, perturbative theory formulated by Mehrotra and Boggs, the J- and temperature dependence of line width parameter is computed for ClO-N_2 and BrO-N_2 systems. The temperature dependence is found to be J-dependent. As per these calculations the value of the line width parameter for the ClO-N_2 system is at least 30% higher at the temperature T = 300 K and also the temperature dependence is different from that of the values of Vatrra et al. However, this disagreement is within the uncertainty range stated by them.
J. Geophys. Res., Green, Paper 0C1803

Electromagnetics

0720 Electromagnetic theory
REFLECTIONS FROM AN INHOMOGENEOUS SLAB
S. Sivaprasad (Dept. of Electrical and Computer Engineering, University of New Hampshire, Durham, NH 03824, USA) R. Vasudevan and H. H. Hubey

The reflection and transmission functions of an inhomogeneous slab are calculated by labelling the wave by the number of reflections it has undergone in the medium. The Riccati equation, satisfied by the reflected amplitude, is decomposed into an infinite set of linear equations by taking into account the number of scatterings taking place inside the medium, and solved by a novel iterative approach. The order-of-scattering reflection functions method presented here and the coupled integral equation approach of the Bremmer solutions for the internal fluxes are set in a unified frame. The solutions of the Riccati equation are computed numerically for the reflection function using the order-of-scattering technique and it is demonstrated that the method leads to better convergence and stability as compared to usual linearization methods.
Rad. Sci., Paper 8051504

0720 Electromagnetic theory
NON-CIRCULAR OPTICAL WAVEGUIDES AND MODAL CHOICE
Yang Shuwen (Chengdu Institute of Radio Engineering, Chengdu, Sichuan, P. R. C.)

In this paper we investigate the propagation characteristics of light in non-circular dielectric optical waveguides based on the microwave-modal experiments. It is found that the attenuation of non-circular waveguides is smaller than that of circular guides and the attenuation of the odd modes is smaller than that of the even modes in non-circular dielectric waveguides. Hence it is profitable to use non-circular optical fibers. Furthermore, it is profitable to choose the odd mode. By using the non-circular guides, we can stabilize the polarization for single mode optical fiber, and the better propagation characteristic is obtained. (Optics fiber, non-circular waveguide, propagation characteristics, mode)
Rad. Sci., Paper 8S0184F

Geochemistry

1610 Chemistry of the atmosphere
THE PHOTODISSOCIATION OF WATER VAPOR IN THE MESOSPHERE
M. Nicolet (Department of Electrical Engineering, Ionosphere Research Laboratory, The Pennsylvania State University, University Park, PA 16802)

An analysis of the photodissociation of water vapor has been made for mesospheric conditions. The simultaneous action of two spectral ranges, namely the Lyman-alpha radiation and the O_2 Schumann-Runge bands, must be considered. The H_2O photodissociation frequency due to Lyman-alpha is represented by

$J(H_2O, Ly\text{-}\alpha) = J_\infty \exp[-4.47 \times 10^{-19} N^{0.917}]$

where N is the total number of O_2 absorbing molecules, and $J_\infty = (4.5 \pm 1.0) \times 10^{-6}$ sec^{-1} for quiet sun conditions, and reaches $(1.2 \pm 0.3) \times 10^{-5}$ sec^{-1} for very active sun conditions. The H_2O photodissociation frequency resulting from the O_2 Schumann-Runge band spectral range is represented by

$J(H_2O, SRB) = J_\infty(H_2O, SRB) \exp[-4.5 \times 10^{-10} N^{0.468}]$, for $N \le 10^{20}$ cm^{-2}, and

$J(H_2O, SRB) = J_\infty(H_2O, SRB) \exp[-4.6 \times 10^{-8} N^{0.364}]$ for $10^{20} < N \le 10^{22}$ cm^{-2}. The mean value which has been adopted for $J_\infty(H_2O, SRB) = (1.3 \pm 0.3) \times 10^{-6}$ sec^{-1} whilst a median value would be $(1 \pm 0.2) \times 10^{-6}$ sec^{-1}.
J. Geophys. Res., Green, Paper 0C1886

Oceanography

4765 Surface waves, tides, and sea level
SEA LEVEL VARIATIONS IN RELATION TO COASTAL FLOW AROUND THE GULF OF ALASKA
R. K. Reed (NOAA, Pacific Marine Environmental Laboratory, Seattle, Washington 98105) and J. D. Schumacher

Adjusted sea level deviations at six tide stations around the Gulf of Alaska were examined in light of our recent knowledge of the flow regime. On the east side of the Gulf, a maximum in the deviations seems to be caused by winter barotropic flow on the shelf. On the north side of the Gulf, the maximum in fall is apparently produced by a marked increase in flow of the baroclinic coastal current. Farther west the seasonal sea level signal is greatly reduced.
J. Geophys. Res., Green, Paper [illegible]

4765 Surface waves, tides, and sea level
SUBTIDAL WATER LEVEL VARIATIONS IN LAKE PONTCHARTRAIN, LOUISIANA
Wen-Jen Chuang (Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana 70803) and W. J. Swenson

Lake Pontchartrain, Louisiana, has two major tidal passes connecting it to Mississippi Sound and thence to the Gulf of Mexico. The subtidal variability in this system and its relation to wind forcing over a 7-month period were examined. The coherence of water level fluctuations in the lake and passes with those of the sound was high at all time scales, and the water level in all data sets responded to the east-west wind at time scales shorter than 15 days. Since the local coastline is approximately in the east-west direction, the results suggest a coupled coastal-lake response. A linear friction model was developed, and it accounted for most of the observed features.
J. Geophys. Res., Green, Paper 1C0035

4770 Turbulence and diffusion
AN INERTIAL SUBRANGE IN MICROSTRUCTURE SPECTRA
P.A. Newberger and D.R. Caldwell (School of Oceanography, Oregon State University, Corvallis, Oregon 97331)

An inertial subrange was found in spectra calculated from vertical profiles of temperature gradient recorded in the bottom layer on the Oregon shelf. An ensemble average of those spectra that were fully resolved and had high Cox number was compared to the universal form. The high wavenumber end of the inertial range was resolved. A relationship between the Kolmogorov constant for temperature, β, and the Batchelor constant, q, was established, $\beta q^{-2/3} = 0.175$ (±0.012). If β = 0.5, as determined from atmospheric data, q = 4.35 (1.28 < q < 6.65) and the transition from the inertial to the viscous-convective range occurs at a wavenumber $k = 0.035\ k_s$ (0.021 < k/k_s < 0.045) where k_s is the Kolmogorov wavenumber.
J. Geophys. Res., Green, Paper 80C1770

Particles and Fields—Interplanetary Space

5380 Solar wind plasma
PLASMA REST FRAME DISTRIBUTIONS OF SUPRATHERMAL IONS IN THE EARTH'S FORESHOCK REGION
E. G. Sentman (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024) C. F. Kennel and L. A. Frank

We present rest frame ion distributions computed from three dimensional observations of upstream suprathermal ions gained by the University of Iowa Quadrispherical Lepedea on ISEE-1. The observations are for a single inbound, midmorning pass starting upstream from the ion foreshock and continuing across the quasi-parallel bowshock into the magnetosheath. The crossing of the ion foreshock boundary is marked by a several minute burst of ions of temperature 100-200 eV moving along the IMF away from the bowshock at 600 km/s relative to the solar wind. The observation of these "reflected" ions is followed by an extended interval of "diffuse" ions of temperatures 2-3 keV flowing at ~ 150 km/s relative to the solar wind and persisting until the bowshock is crossed. The diffuse ion β has a value of approximately 6 in the region of the suprathermal ions, exceeding the normal thermal ion β of the solar wind by roughly an order of magnitude. Both types of suprathermal ions constitute roughly 2% of the total ion density, and carry a parallel heat flux of ~ 2×10^{-2} ergs-cm^{-2}-sec^{-1}. When integrated over an assumed 10 x 10 R_E bowshock emission area, this implies an upstream dissipation that may approach 10^{17}-10^{18} ergs/sec, comparable to a modest substorm.
J. Geophys. Res., Blue, Paper 1A0017

Particles and Fields—Ionosphere

5550 Low-latitude ionospheric currents
3-50 METERS WAVELENGTH PLASMA INSTABILITIES IN THE EQUATORIAL ELECTROJET. 2. TWO-STREAM CONDITIONS
C. Hanuise and M. Crochet (Laboratoire de Sondages Electromagnétiques de l'Environnement Terrestre, Université de Toulon et du Var, 83100 Toulon, France)

New multifrequency measurements with a HF radar in the equatorial electrojet have extended the range of wavelengths investigated during high drift velocity conditions to 50 meters. It is shown that the so-called type 1 spectra can be detected at all wavelengths, their phase velocity has a value given by the threshold for instability in the full dispersion equation and is constant with elevation angle and time when corrected for neutral wind effect. Spectral width increases with wave number following a law k^n, n ≈ 0.7 but is constant with elevation angle. Ratio of spectral width to mean doppler shift is of the order of unity at the lowest wave number and decreases as k^{-n}, n ≈ 0.6. These results are compared to the existing numerical simulations and theoretical works.
J. Geophys. Res., Blue, Paper 1A0002

5550 Low-latitude ionospheric currents
5-50 METERS WAVELENGTH PLASMA INSTABILITIES IN THE EQUATORIAL ELECTROJET. 1. CROSS-FIELD CONDITIONS
C. Hanuise and M. Crochet (Laboratoire de Sondages Electromagnétiques de l'Environnement Terrestre, Université de Toulon et du Var, 83100 Toulon, France)

Electron density irregularities detected with coherent radars in the equatorial electrojet have been studied mostly at wavelengths between 3 and 10 meters. For low drift velocities they have been interpreted by the cross-field instability. Longer wavelengths have been extensively observed with a multifrequency HF radar system installed in Ethiopia. Data gathered for drift velocities lower than 200 m/s are presented. From 5 to 50 meters, the measured phase velocity varies with wavelength and elevation angle as predicted by the linear theory. Spectral width increases with wave number but is constant with elevation angle. Ratio of spectral width to mean doppler shift is of the order of unity and indicates that strong turbulence has to be included in non linear theories. These results are studied in light of recent numerical simulations and theoretical works.
J. Geophys. Res., Blue, Paper 1A0001

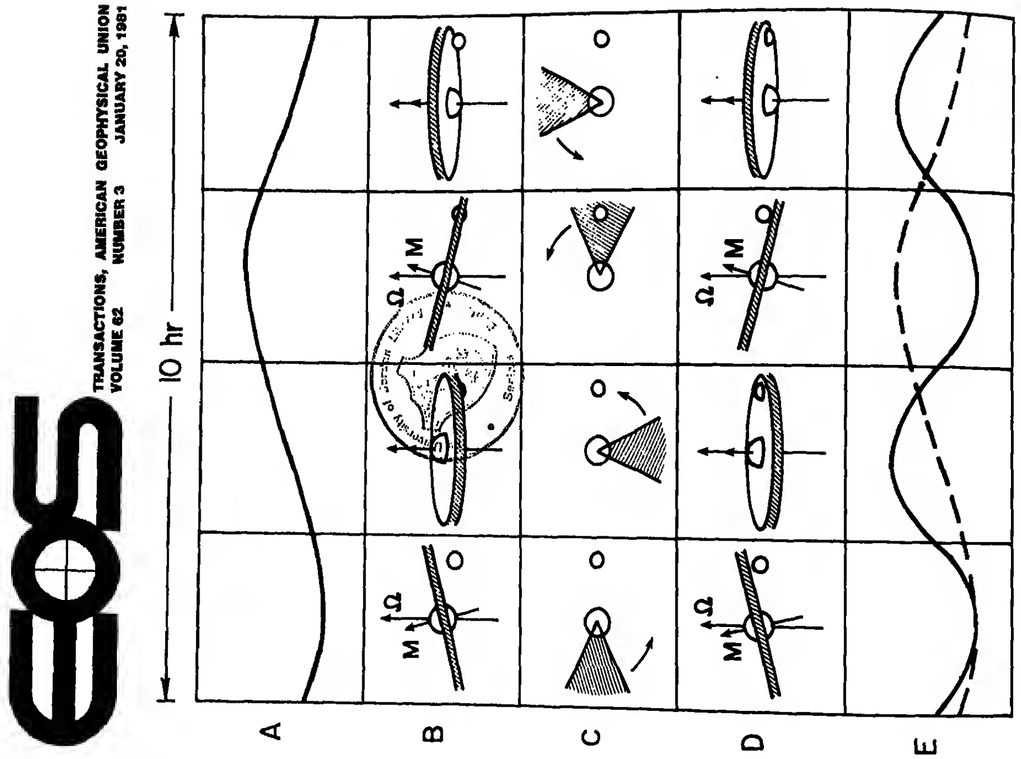
5560 Particle precipitation
THE AURORAL ELECTRON PRECIPITATION DURING EXTREMELY QUIET GEOMAGNETIC CONDITIONS
Ching-I. Meng (Applied Physics Lab., Johns Hopkins Univ., Laurel, Md., 20810)

The electron precipitation over the polar regions during extremely quiet geomagnetic conditions is examined based on data from 5 years of DMSP observations. A total of 12 periods were selected for this study on the basis of prolonged, extremely low values of the Kp index which persisted for at least two consecutive days. The interesting electron precipitation features can be summarized as follows:

(1) At all times, precipitation indeed occurred over both the northern and southern polar regions with significant intensity. The precipitating intensities were one to two orders of magnitude below the level for normal, quiet (Kp ≤ 2) auroral oval precipitations.
(2) The measured precipitating electrons were very soft, most having energies below 1 keV. The observed fluxes of low energy electrons between 50 eV to a few hundred eV were often merely the high energy tail of an extremely soft precipitation.
(3) Electron precipitation with a most probable energy of a few keV (harder than that of the auroral oval) can form a band detached from and equatorward of the morning auroral oval.
(4) A dramatic feature of the electron precipitation of the extremely quiet magnetosphere is the unexpectedly wide latitudinal extent of the low energy electron precipitation. It spreads into the high latitude polar regions to at least 85° gm lat.
J. Geophys. Res., Blue, Paper 1A0083

5580 Wave propagation
GENERATION OF LANGMUIR WAVES BY NON-LINEAR WAVE-WAVE INTERACTION IN THE IONOSPHERE
J.C. Cerisier (Laboratoire de Géophysique Externe, 4 Avenue de Neptune, 94100 Saint-Maur, France) J. Lavergnat, J.J. Sihouey, M. Pelfer

The non-linear interaction between two parallel high-frequency electromagnetic waves can generate either an electron plasma wave or an extraordinary wave depending upon the angle of propagation with the external magnetic field (either θ = 0 or θ ≠ 0). When propagating in the inhomogeneous ionosphere, the extraordinary mode couples to the plasma wave and the results obtained in both cases turn out to be identical. The plasma wave can be detected from the ground through the enhancement of the amplitude of the plasma lines associated to the scattered spectrum of a third electromagnetic probing wave. The amplitude of the electrostatic plasma wave and of the scattered plasma lines are calculated. The steady-state conditions (in time and in space) between the plasma wave pulse and the probing pulse are evaluated and discussed for the Sisnet sounder. (Wave-wave interaction, ionosphere, plasma line).
J. Geophys. Res., Blue, Paper 1A0006



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New Origin of Life Theory

A new theory about the chemical evolution of life proposes that simple self-replicating chemical systems rather than complex ones could have been the precursors of living cells more than 3.5 billion years ago. The new theory, published in a recent issue of the *Journal of Molecular Evolution*, was developed by David White, an assistant professor at the University of Santa Clara, Calif.

White proposes that the first chemical ancestors of life were themselves 'alive' only in the sense that they could reproduce themselves and may have been far simpler than previously believed. The prevailing theory of the chemical evolution of life holds that natural energy, such as lightning, sunlight, and heat, interacted with the atmosphere, soils, and oceans of primordial Earth. The continuous interaction and evolution over millions of years eventually produced complex chemical systems that could reproduce themselves and that led to the first living cells. The problem lay in getting the right chemical building blocks together in the right place at the right time. The process that led to living cells is easier to explain, however, if the necessary components are simple and few in number.

According to White's theory, very simple self-replicating systems could have appeared very early in chemical evolution. A key to the theory—whether these simple molecules would be capable of reproducing themselves—has been demonstrated by the recent results. Experiments done at Santa Clara, and jointly at the Ames Research Center, showed that under simulated primitive Earth conditions a short chain of amino acid molecules can produce longer chains of another amino acid and still longer chains of a catalyst molecule. The catalyst molecule functions like an inefficient, primitive enzyme. It is the first such simple molecule to demonstrate the vital ability to catalyze (chemically facilitate) a reaction—an ability essential for life. The 'proto-enzyme catalyst,' as it is called, was suggested by White's theory. The discovery of the catalyst molecule and its function is important but not sufficient for the origin of a self-reproducing system of molecules. Nucleic acids are required, as well as molecules that are able to carry genetic heritage to the next generation. Computer modeling based on known properties of molecules showed that, in theory, a self-reproducing system could be amazingly simple. In principle, the simplest possible system, called an anogen by White, would consist of two proto-enzyme amino acid chains. This assumes that molecules from which amino acids and nucleic acids could be built were already present in the primordial environment, an assumption that has gained some support from laboratory simulation experiments.

In this theoretical system, the two short proto-enzyme amino acid chains would be able to synthesize themselves and two nucleic acid chains, which in turn tell the amino acid chains how to make all four products of the system. This 'four-component system' (the two amino acid chains plus the two nucleic acid chains) is theoretically able to make many more such systems from the stock of building blocks which are presumed to have existed in the primordial environment.

Just how the nucleic acids would specify the exact amino acid chains remains to be demonstrated, which is a problem for all such theories. One advantage of White's theory is that the accuracy of the specification process need not be very great.

'We may find that a four-component system is too simple,' commented White. 'We may have to look for more complexity to get realistic self-reproduction. However, the success of these first experiments suggests that simple catalytic processes may be common in nature.'

An array of experiments is now planned that will use the most commonly found biological building blocks to look for other simple catalysts and nucleic acid patterners. The goal is to discover whether self-reproducing molecules can organize themselves in laboratory experiments. Another advantage of the new theory is that it provides guidelines for the design of future experiments to test its predictions.—*PMB*

RACOONs Amass Wind Data

Balloons, not furry little animals, are being developed to provide new, inexpensive methods for gathering weather data in the tropics.

RACOON—short for radiation-controlled balloon—is a zero-pressure balloon which will be used to provide stratospheric wind data for equatorial regions, according to the National Center for Atmospheric Research. These data are unavailable from satellites. Currently, the global rocket network gathers tropical wind measurements for weather forecasting; however, the network is being phased out.

The helium-filled RACOON balloon, once aloft, rises to an altitude of 38,100 m at dawn when the helium gas is heated by the sun. At twilight the helium's volume shrinks, and the balloon sinks to around 18,300 m, above the tropopause. The balloon, warmer than the ambient −100° F temperature, retains its buoyancy.

Unlike superpressure balloons, RACOON balloon bags are not strong enough to withstand internal gas pressure that exceeds the surrounding air pressure. For this reason, as the zero-pressure balloon rises, helium is vented to the atmosphere to maintain an equilibrium between the inside and outside pressures. Superpressure balloons, requiring costly materials and precision manufacturing, do not vent gas and are too expensive for routine meteorological monitoring.

Research on zero-pressure balloons recently received a boost with the setting of a flight duration record. Launched by NCAR scientists September 18 near Devil's Island in French Guiana, the zero-pressure RACOON balloon circled Earth and landed in the Amazon jungle 38 days later, surpassing the earlier record of 6 days. Fully inflated, the balloon resembles a semi-translucent, slightly pear-shaped beach ball. It has a helium capacity of nearly 19,900 cubic meters. Previous RACOONS were unable to stay aloft for a long period of time and floated lower, owing to the heavy equipment and ballast it had to carry.

Follow-up tests of the RACOON system are planned for this month.—*BTS*

Antarctica: As Seismic As Other Plates

Antarctica shakes, rattles, and rolls just as much as other slow-moving plates. Emile Okal, a Yale University seismologist, told colleagues at the AGU Fall Meeting that although the Antarctic plate is not moving across the earth as fast as other continents, it has a seismicity similar to other plates. His findings refute the claim that a ring of spreading ridges that surrounds the plate leaves Antarctica stress free.

The small number of reports of plate seismicity, Okal explained, has been used to argue that the ridges that surround the plate are unable to transmit tectonic stresses and would make the Antarctic plate motionless and free of seismic stress. However, when Okal added up the total seismic energy released during the last 55 years, he found it similar to that of the African plate, which is comparable in size.

He then computed the yearly energy release per unit length of ridge bordering the plate and found a close match: Antarctica's seismic release is 3.4×10^{17} ergs/yr/km, compared to Africa's 2.3×10^{17} ergs/yr/km.

'These figures show that, far from being aseismic, the Antarctic plate releases fuel about the same amount of energy per length of surrounding ridge as does Africa, whose kinematics and size are similar,' Okal stated. Seismic activity occurs primarily in the oceanic regions of the plate; the continent itself has only low seismicity.

Key to previous misjudgments about Antarctic seismic events is that they occur relatively infrequently, he said. Okal judges the recurrence period at 45 to 50 years. 'This makes a large difference in seismic reports,' he said, 'because 50 years ago detection levels were very poor.' Southern latitudes lacked good seismic stations then, he added. 'Detection capabilities have improved considerably over time,' Okal asserted. Stellon coverage became permanent in 1963, following the installation of the Worldwide Standard Seismograph Network (WWSSN).

Although seismologists have yet to complete their portrait of Antarctica, they do know that about half of the seismic energy release occurs in the southeastern Pacific Ocean region. The region also has the fastest spreading rates. Seismicity is notably absent, though, from several regions: western Indian Ocean, South Atlantic, and southwestern Pacific Ocean basin.

What causes site-specific intraplate seismicity? Okal hypothesizes that weaknesses in the plate caused by a history of tectonism could play a crucial role. Based on analysis of the 21 earthquakes in the last 55 years, Okal proposes that a zone of preferential stress release exists. This zone lies in the wake of the north northwestward movement of the triple junction of three plates: the Pacific, Antarctic, and Nazca. This line of local maximum age is the zone of weakness, Okal said.

Little deformation of the plate occurs during the release of intraplate stress, Okal calculates. The average deformation—in the form of horizontal compression—in the southeastern Pacific region of the plate is 1 mm/yr, or 5% of plate growth in that region. This region is 'by far the most active,' Okal noted. The horizontal compression is in the direction of spreading or ridge push, he added.—*BTS*

Mining's Impact on Groundwater Assessed

Detailed studies have indicated that groundwater is contaminated in the immediate vicinity of many mines in the eastern United States. However, no underground mines and very few refuse disposal areas have monitoring systems that can provide adequate warning of impending threats to groundwater quality.

This was one of the conclusions of a 3-year study by Geraghty & Miller, Inc., a firm of consulting groundwater geologists and hydrologists based in Syosset, New York. The study focused on mines east of the 100th meridian. These mines will produce an estimated 1.1 billion tons of coal and 200 million tons of waste by 1985.

In addition, the study concludes that 'engineering and hydrologic controls instituted during or after the mining process are seldom fully effective in controlling adverse effects on groundwater.' Diverting groundwater around mines, however, by using dewatering or connector wells is promising for minimizing groundwater impacts in some hydrogeologic settings, according to a report by Geraghty & Miller.

The report, prepared for the Industrial Environmental Research Laboratory of the Environmental Protection Agency, singles out 31 counties—predominantly in western Pennsylvania and southern West Virginia—that have 'a greater potential for significant adverse groundwater impacts from future underground mining.' These counties met two of the three criteria developed for the study to assess mining's effects: counties with underground coal reserves greater than 455 million metric tons; counties with over 1.06 million gallons per day of groundwater pumping; and areas within these counties that have available groundwater suitable for small industrial and public supplies.

Ocean Drilling Surveys Planned

As a continuation of the International Phase of Ocean Drilling (IPOD), the *Glomar Challenger* is slated to drill in the Pacific and North Atlantic oceans during 1982–83. In preparation for the drilling, the Joint Oceanographic Institutions (JOI), Inc. will manage the site survey program during 1981–82. These site surveys will be focused to support four programs: a hydrogeology study on the equatorial East Pacific Rise flank; a study of Mesozoic sediments in the western Pacific; a study in sedimentation of the equatorial Pacific basin; and a study of the geochemistry of the North Atlantic ocean crust.

JOI has issued a request for proposals for the United States site survey program. Proposal deadline is March 5. For additional information, contact JOI, Inc., 2600 Virginia Avenue, N.W., Suite S12, Washington, D.C. 20037.

New Coastal Studies Center

The Scripps Institution of Oceanography has established a new center that is charged with coordinating the research and teaching of nearshore ocean processes.

Under the director of Douglas L. Inman, who specializes in inshore ocean waves, currents, and sediment transport, the Center for Coastal Studies will be the focus of international research programs as well as ongoing local, regional, and national studies. Members of the center's Shore Processes Study Group have advised many U.S. agencies and foreign governments on aspects of coastal planning, data acquisition and processing, and concepts for coastal protection and sediment management. Long-term cooperative exchange programs are under way with scientists from Israel and Italy; plans are being made for similar programs with Egypt and the People's Republic of China.

Marine archeology and the migration of early men in the coastal region of North America are also being studied at the center.

Voyager 2 on Path to Uranus

The continuation of Voyager 2 on a trajectory that would take it to Uranus in 1986, after flying past Saturn this summer, appears certain. Under the approved plan, the spacecraft will encounter Uranus at a distance of 107,000 km on January 24, 1986, making measurements and taking pictures as it speeds past and heads for a possible encounter with Neptune.

The Uranus encounter will provide the first close-up look at that planet. Uranus is the seventh planet outward from the sun and is twice as far from the sun as Saturn; it rotates on its axis at a tilt of 98°.

The decision to fly past Uranus is, in effect, a decision to retain the present trajectory. If JPL had decided against a Uranus encounter, then a retargeting of the Voyager 2 would have been required. Voyager 2 was launched August 20, 1977. The sister ship to Voyager 1, Voyager 2 flew by Jupiter in July 1979 and will encounter Saturn on August 25, 1981.

Voyager 1's trajectory through the solar system was selected to optimize the scientific objectives at Jupiter, Saturn, and Titan. The path of Voyager 2 was chosen to provide a course to Jupiter, Saturn, and Uranus, and perhaps Neptune. This path does not provide a close-up approach to Titan or a Saturn ring occultation, which were among the goals of the Voyager 1 mission. The final decision to remain on the trajectory had to await the successful outcome of Voyager 1's

(*News* cont. on page 34)

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Cover. High speed diamond drilling rig operating at Reydarfjordur, eastern Iceland, during the summer of 1978. Using this rig, an international scientific group (Iceland, U.K., Canada, U.S.A., West Germany, Denmark) was able to obtain a 1920-m section (99.7% recovery) which formed the deeper part of a 3-km vertical section of Icelandic crust. The drill site is located where crustal dilation by dikiing is 10% at sea level—some of these dikes are visible in the hill in the background (see also, 'Drilling Plans,' *EOS*, 61 (10), 105, 1980, and *Nature*, 281, 347–351, 1979). (Photo courtesy of J. M. Hall, Department of Geology, Dalhousie University, Halifax, Nova Scotia.)

(News cont. from pago 33)

closo encounter with Saturn and Titan in November 1980.

Voyager 1 lies achievod the prescribed Saturn/Titan scientific objectives. Tho assessment of tho health of tho Voyager 2 spacecraft and instruments indicates that there is a reasonablo probability that tho 5-year journey to Uranus can be ondured and a scientifically productivo flyby can be achieved. 'On this basis, therefore, tho decision has been made to retain the present Uranus trajectory for Voyagor 2,' said Andrew J. Stofan, acting associate administrator for spaco science. He pointed out that retargeting of the spacecraft to provido another closo Titan flyby could have been made as late as early 1981.—*PMB* ◆

Mutch Memorial Plaque Unveiled

A plaque commemorating Thomas A. Mutch, former associate administrator of NASA's Office of Spaco Scionco, was unveiled in a ceremony at the National Air and Spaco Museum earlier this month. Mutch was lost while mountain climbing in the Himalayas in October (*Eos*, October 28, p. 693). The plaque will be affixed to the Viking 1 landor, renamed the Mutch Memorial Station, during a future Mars mission.

A follow-up Mars mission has been suggested for the 1990's, and although no funding is available now, there is talk, NASA says, of sending a roving spacecraft to Mars that would affix the plaque, scoop up some Martian terrain, and bring the sample back to earth. Until the plaque can be transported to Mars, it will remain at NASA headquarters in Washington, D.C.

At the same ceremony, early in January, NASA accepted a $60,000 check from The Viking Fund, a private organization under the auspices of the American Astronautical Society. The check represents individual contributions to support the continued operation and scientific analysis of the Viking 1 lander on Mars.

To seek additional support for Viking, NASA has designated July and August, the fifth anniversaries of the Viking arrival at Mars, as Viking Fund months. The Fund's donation will pay for the acquisition by the NASA Deep Space Network of data transmitted by the Viking lander during those months. ◆

Science Education Research Program

A deadline for receipt of research proposals on science literacy and science, technology, and society has been set by the National Science Foundation's Research in Science and Education (RISE) program. March 9 is the target date set by NSF to insure that proposals are considered for the RISE fiscal 1981 budget, which is expected to total $6 million.

RISE's purpose is to examine the science literacy of the U.S. public and to determine the public's needs. Although schools have been responsible for teaching science, only 50% of the American public receive formal science instruction after 15 years of age, according to NSF. Those who do not receive formal training must rely on a combination of electronic and print media, museums, and public agencies for science information.

For additional information and RISE guidelines on the preparation of formal proposals, contact the Program Director for RISE/SEOR, NSF, 1800 G Street, N.W., Washington, D.C. 20550, or call 202-282-7745. ◆

New Map Data Catalog

Map byproducts, including aerial photographs, color separations, map data in computer form, and other materials used in or produced during mapmaking, are described in a new catalog published by the U.S. Geological Survey.

The 48-page hardcover catalog is the first listing of the unpublished USGS civilian cartographic holdings. It covers such items as mapping photographs, computer-enhanced LANDSAT pictures of Earth, cartographic data in computer form, microfilm and microfiche records, and a variety of features, including color separations, made in compiling and printing maps. The catalog also describes out-of-print maps available from USGS, along with land-use and land-cover maps, and other unusual items, such as slope maps and orthophotoquads. The catalog explains how to order advance copies of maps before they are published.

'Map Data Catalog' is available for $3.50 from the USGS, Branch of Distribution, 604 Pickett Street, Alexandria, Virginia 22304. Orders must include check or money order, made payable to USGS. A colorful poster that summarizes the contents of a catalog, 'MiniCatalog of Map Data,' is available free upon request from NCIC, USGS, 507 National Center, Reston, Virginia 22092. ◆

Geophysicists

J. C. I Doogo, secretary of the Royal Irish Academy, has been elected secretary general of the International Council of Scientific Unions. A member of the International Union of Geodesy and Geophysics, he is the head of the civil engineering department at University College in Dublin.

M. F. Meier, president of the International Association of Hydrological Sciences, has been made an honorary member of the International Glaciological Society.

Thomas E. Pyle has been appointed deputy director of the National Ocean Survey. He was formerly head of the Office of Naval Research's Marine Geology and Geophysics Program and director of the ONR Detachment Washington Liaison Office.

Harold C. Urey, 87, a major contributor to the development of the atomic bomb, died January 6 in La Jolla, California. In 1934 he was awarded the Nobel Prize for chemistry for his discovery of deuterium. Urey was the director of the atomic bomb project at Columbia University during World War II. He had been professor-at-large at the University of California since 1958. Urey was an honorary fellow of AGU.

New Publications

Quantitative Seismology, 1, Theory and Methods

K. Aki and P. G. Richards, W. H. Freeman, San Francisco, xiv + 557 pp., 1980, $35.00.

Reviewed by Freeman Gilbert

Quantitative Seismology, by Aki and Richards, will find a prominent place in the library of every seismologist. The two-volume work, of which the first is reviewed here, treats seismology as a branch of physics with a well-defined theoretical basis coupled with an observational program providing data of high quality. Very roughly, the first volume is devoted to the theoretical basis of seismology and the second to data analysis, interpretation, and problems of inference.

After a brief introductory chapter, the authors devote chapter 2 to the basic elements of the theory of elasticity. The conservation equations for linear and angular momentum are derived, and the classical constitutive relations are introduced. The concept of superposition for linear systems is introduced, and the Green's functions notation is used to derive compact representation theorems.

Dislocation sources and volume sources are introduced in chapter 3, and radiation from a point source is discussed in chapter 4. Here we meet *P* waves and *S* waves for the first time. A generalization of the far field expressions for homogeneous media leads to a discussion of ray theory in heterogeneous media, which is followed by a discussion of radiation patterns of body waves in a radially stratified medium.

The authors use the technique of introducing their mathematical methods in small doses while always emphasizing the physical meaning of their results. As a consequence, each succeeding chapter is mathematically only slightly more difficult. The procedure is an effective one and permits the authors to adopt an economical style without sacrificing either continuity or content.

Chapters 2-4, with their basic theorems and concepts, make the transition to boundary value problems a smooth one. The reflection, transmission, and conversion of plane *P* and *S* waves at a plane discontinuity are treated in chapter 5. Inhomogeneous plane waves are introduced, and the basic properties of Rayleigh and Stoneley interface waves are derived. Chapter 5 closes with a brief discussion of the effects of attenuation and anisotropy.

Chapter 6 is the last, most difficult, and most interesting of the introductory chapters. It is devoted to Lamb's problem, the problem of the interaction of cylindrical and spherical waves with a plane interface. Here, the aspiring theoretical seismologist cuts his teeth. The classical approach of the Weyl and Sommerfeld integrals is developed and approximate results derived via steepest descents. The exact solutions, obtained by the operational methods of Cagniard, de Hoop, and Pekeris, are then presented. The reader is exposed to a detailed study of the problem and its methods of solution. Complex variable theory and contour integration are used extensively but always with an eye to the physical interpretation of the results. Consequently, the reader is presented with new insight and understanding of diffracted pulses, head waves, interface pulses, and leaking waves.

It is the authors' intent that chapters 2-6 be introductory in nature, a sort of prologue to the heart of the first volume, chapters 7-9. They have been successful. It is quite evident that considerable care and effort have gone into the structure and content of chapters 2-6. Having assimilated the material therein, the reader is prepared for the following chapters on surface waves, free oscillations, and body waves.

The propagation and dispersion of surface waves is the topic of chapter 7. The concepts of phase velocity and group velocity are introduced by the use of the method of stationary phase, and the relation between spatial and temporal attenuation is derived. The bulk of the chapter is devoted to the basic boundary value problem for a stratified half-space.

Both the ODE approach and the variational approach are described. In the ODE approach, the authors expound the popular methods of numerical integration, the Thomson-Haskell matrix method, and the method of minors. The variational method is used to derive functional derivatives of phase velocity with respect to elasticity and density and to elucidate the Rayleigh-Ritz method for computing eigenvalues and eigenfunctions. The chapter concludes with Rosenbaum's classic theory of leaky modes. Given the identity and reputation of the authors, it is no surprise that this chapter on surface waves is up to date and very well written. It provides the reader with the knowledge and the methods to approach a research problem in this important branch of seismology.

Chapter 8, on free oscillations, could have preceded chapter 7 with some advantage to the logical structure of the text. In this way the transition from free oscillations to traveling waves in a spherically stratified medium to surface waves in a plane stratified half-space would appear in an orderly manner. It is a small point and detracts not at all from the quality of the book.

After deriving the Lagrange-Rayleigh excitation formula for the normal modes of a mechanical system, the authors introduce vector spherical harmonics and show the basic decomposition for a stratified sphere into spheroidal and toroidal modes. The effect of self-gravitation is included in the derivation of the governing ODE for free oscillations. The eigenvalue problems here are very similar to the ones in chapter 7, and they are solved with similar techniques, the two most used ones being Rth order, one step methods for the ODE and the Rayleigh-Ritz method. Some observational results, principally for the Colombian earthquake of July 31, 1970, are presented to illustrate the methods used in very long period seismology. The chapter closes with a brief discussion of splitting caused by the rotation of the earth.

Chapter 8 is a very good introduction to the subject. It is basic material that must be mastered by anyone desiring to become a research worker in low frequency seismology. The growth in the subject has been very rapid in the past decade, so much so that a separate text could be devoted to it.

The propagation of body waves is the subject of chapter 9. It is easily the most technically demanding chapter in volume 1. The heterogeneity of the earth, particularly its major discontinuities in structure, leads to some challenging problems in the branch of seismology embraced by body waves. Classical ray theory, first discussed in chapter 4, is extended in chapter 9, and the reduced travel time, the integral over depth of the vertical slowness, is introduced. This variable, commonly named the tau variable, is ubiquitous in seismology generally and plays a central role in the present chapter.

Both plane layered media and smoothly stratified media are considered in detail. For the former, the operational method of Cagniard and others as well as the reflectivity method are presented. For the latter, WKBJ theory and the partial wave expension are utilized. There are numerous examples to illustrate the methods. For instance, the frequency dependence of diffracted *P* waves is discussed by way of the Watson transformation (really due to Cauchy), and generalized PKP waves form the subject of the whispering gallery effect. In every case, the presentation is well motivated and is clearly stated.

Volume 1 closes with a chapter on seismometry. The standard types of seismographs are discussed and their response equations derived. Seismic accelerations rangs from 1 g in the epicentral area of some earthquakes to 10^{-11} g or less for free oscillations excited by a moderate (M_s = 6.5) earthquake. Several types of seismographs are needed to cover such a very large range of signal amplitudes, and chapter 10 describes them in enough detail for the reader to grasp the basic ideas. Modern seismometry is a large subject and could support a textbook quite easily.

Quantitative Seismology is a very successful book. It is well designed for teaching a graduate course in theoretical seismology and is destined to become the standard reference on the subject. There is an extensive bibliography, a well prepared index, and a variety of figures, each carefully prepared, well captioned, and coordinated with the text. Each chapter is followed by a well chosen set of illustrative problems. Aki and Richards have done a great service for the rest of us.

Freeman Gilbert is with the Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, California.

Numerical Modeling of Marine Hydrodynamics

H.-G. Remming and Z. Kowalik, *Elsevier Oceanogr. Ser.*, Elsevier, New York, xii + 388 pp., 1980, $83.00.

Reviewed by R. W. Garwood, Jr.

At the invitation of the Polish Academy of Science, Hans-Gerhard Remming presented a series of lectures entitled 'Numerical methods and their applications in shallow water areas' during April 1977 in Gdansk. Zygmut Kowalik has assisted Remming in assembling this lecture material and in combining it with some supporting theoretical subject matter into book form and in translating it into English.

To date there exists no textbook on numerical modeling of dynamical processes in the ocean, and any contribution that could fill this gap would be welcome. The rather promising title is misleading because it implies a more general treatment of ocean dynamics than is in fact presented. A more fitting title would have properly emphasized the primarily shallow-water applicability of the subject matter.

The list of numerical methods broached is not exhaustive, but the reader is exposed at least briefly to many of the standard techniques: finite differencing, stability and convergence criteria, iterative methods, physical versus numerical solutions, nonlinear methods, filtering, explicit and implicit schemes, and Galerkin methods. Throughout the text, numerical techniques are introduced informally and only as required in solving particular dynamical problems. The authors frequently invoke the adjective 'well known' in referring to numerical techniques as they are introduced in the text. Even though the development is frequently cursory, an extensive list of up-to-date references is provided at the end of each chapter.

The chapter and section format is based upon dynamical topics rather than upon numerical techniques, but no strong physical foundation is laid. Although the first chapter does present the basic equations of motion, it appears to have been added as an afterthought. Lack of any mention of thermodynamics at this juncture tips the reader off to the limited utility of the contents of the following chapters: Stratification and buoyancy effects will not be treated in depth. There are brief discussions of the effects of known (measured) density structure upon baroclinicity and upon the vertical exchange of momentum, but no consideration is given to modeling of the temperature and salinity fields.

The second and third chapters deal with steady motion: first some general numerical techniques for solving steady state systems of equations followed by a collection of some specific steady state problems in hydrodynamics. These problems range from classical ones such as Stommel's wind-driven circulation to a presentation of more recent developments in the understanding of turbulent boundary layer flows involving second-order closure using the turbulent kinetic energy budget.

Unsteady problems and accompanying numerical methods are combined into a single chapter. Again, little attention is given to stratification. The lack of a section on mixed layer modeling is a notable omission even for a treatise on shallow-water dynamics.

The next two chapters on tidal models in ocean basins, coastal zones, estuaries and rivers, and the following chapter on the modeling of diffusion and dispersion of pollutants are the high points of this book. Clearly, it is the pursuit of the applied aspects of these general topics that is most interesting to the authors and gives rise to the expanded treatment here.

Even though the text is typewritten and is occasionally disjointed because of the English translation, it is quite readable, and typographical errors are few.

In conclusion, this text is best suited to those who are already versed in dynamical oceanography and who have some experience with numerical methods as well. It does help to fill the gap in readily available material on numerical modeling in oceanography, and it can be a useful addition to the reference library of any modeler of ocean dynamics. However, the value of this book as a basic textbook is not comparable to analogous texts in meteorology. Perhaps this is being too critical of a volume that was never intended to be more than a compendium of two scientists' salient experiences in hydrodynamical modeling.

R. W. Garwood, Jr., is with the Naval Postgraduate School, Monterey, California.

Classified

Sedimentary or Low Temperature Geochemist. This is an assistant professor, tenure track position, although exceptional candidates of higher rank will be considered. We are looking for a geochemist to complement our strong programs in sedimentology, hydrogeology, organic geochemistry, and basin analysis. The teaching load is three courses per year – one beginning level geology course, an upper level geochemistry course, and a graduate course of his/her choosing. Introductory biology and summer field camp are also taught on a long-term rotating basis. A well equipped laboratory and computer facilities are available. The potential exists both for university funding and for cooperative research.

The successful candidate will be expected to conduct an active research program leading to publications. Applicants should submit a letter of application, resume, a copy of each transcript, and have three supporting letters sent to

Chairman
Department of Geology
University of Missouri
Columbia, Missouri 65211

The University of Missouri is an equal employment opportunity employer

Oceanographic Mooring Technician. The Marine Science Program at North Carolina State University (Raleigh) is expanding its oceanographic technical services group and is currently seeking a technician familiar with the design and deployment of deep-sea current meter mooring arrays, as well as with shipboard oceanographic sampling techniques.

Qualifications include a degree in science or engineering with some electronics background and two years field experience or an equivalent combination of education and experience. Salary commensurate with education and experience. Send resume and names of references to Personnel Services, North Carolina State University, P.O. Box 5067, Raleigh, NC 27650

An equal opportunity employer

Postdoctoral Research Associate. Oceanography Department of the Naval Postgraduate School seeks recent graduate to study the hydrodynamics through numerical ocean modeling of the physical oceanographic processes active in the vicinity of the arctic ice edge off Alaska. Problem areas include the effects of the complex bathymetry on the circulation and frontal formation, the dynamics associated with interleaving of water masses at the edge, and the mechanisms involved in air-ice interaction will be performed in the context of an ongoing observational program which has acquired data and developed insights over the course of several years.

To be considered by March 1981 and is renewable annually. Salary depends upon qualifications. Send resume and three names and addresses of those referees to Faculty Search Committee, Dept. of Oceanography, Naval Postgraduate School, Monterey, CA 93940

Equal opportunity, affirmative action employer

Assistant Professor-Northern Illinois University. Applications invited for a probable tenure track faculty position beginning August 1981. Candidates are being sought who are specialists in one of the following areas: igneous petrology, economic geology or mineralogy. The Ph.D. degree is required. The successful candidate will teach graduate and undergraduate courses and will be expected to pursue an active program of research in his/her specialty.

Application should include the resume and the names and addresses of three persons who could serve as references. Inquiries and applications should be addressed to:

L. D. McGinnis
Search Committee
Department of Geology
Northern Illinois University
DeKalb, IL 60115

Application deadline April 15, 1981

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Faculty Positions in Geology-University of Alabama. The Department of Earth Sciences is seeking applicants for a tenure track position at the assistant professor level. The Ph.D. degree is required. The selected person will teach one or more courses in geophysics at the undergraduate level, basic courses in the earth sciences, supervise senior or independent research projects, will develop one or more elective courses in that person's specialty and will develop a research program.

The Department of Earth Sciences contains eight full time faculty and graduates approximately ten students each year. Equipment and facilities include a geochemical and sedimentological laboratory, well preparation equipment, student and research petrographic microscopes, thin section preparation equipment, electronic geophysical equipment, seismic refraction and reflection equipment, and a computer facility. Graduate students are supported with research assistantships and teaching assistantships. Applicants should have a strong undergraduate background in geology and geophysics and a graduate degree in geophysics or geology with emphasis in geophysics. Graduate training and experience in seismology is desirable. Applicants should submit a resume, transcripts, three letters of reference, and a brief statement of research interests to Michael J. Nelson, Earth Science Department, University of Alabama in Birmingham, Birmingham, AL 35294 (205/934-8551). By May 1, 1981 the position will remain open until filled.

The University of Alabama is an affirmative action/equal opportunity, affirmative action employer.

Oxochemistry/Brittle Deformation, University of New Brunswick. The Department of Geology has a tenure track position available from July 1, 1981 at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students.

Applications will be accepted in the following fields: geochemistry of ore bodies, exploration, environmental or soil geochemistry, brittle deformation, rock mechanics or site engineering.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Seismologist. The University of Nevada Seismological Laboratory invites applications for the position of lecturer/research seismologist. Candidates with interest in seismological research related to earthquake hazard, earthquake prediction, theoretical source mechanisms, and/or seismic signal characteristics at regional distances are encouraged to apply. Teaching duties will consist of one undergraduate or graduate course per semester plus participation in graduate seminars.

Ph.D. degree in geophysics with at least three years research experience in earthquake seismology is appropriate for this position. Salary up to $30,000 for twelve-month contract, depending on background and experience. Position two thirds supported by state, one third by grants and contracts. Available on or after 1 May 1981.

Deadline 1 March 1981.

Candidates should send a letter of application, list of publications, statement of teaching and research interests, transcripts and names of five references to Alan Ryall, Director, Seismological Laboratory, University of Nevada, Reno NV 89557

AA/EOE

Staff Scientists/Ocean Margin Drilling Program. Joint Oceanographic Institutions, Inc. (JOI, Inc.) has immediate openings for two staff scientists to fill the positions of:

- Field Programs Coordinator
- Downhole Measurements Coordinator

at the Ocean Margin Drilling (OMD) Science Programs Office. Individuals filling each of these positions will report to the OMD Chief Scientist. They will be required to provide staff support to advisory committees in their area of concern, and will be responsible for implementing programs recommended by the OMD Science Advisory Committee, including oversight of the performance of individuals or groups under contract to JOI. Both positions require a Ph.D. in an appropriate area of earth science and appropriate experience. The OMDP is funded for FY 81. Initial appointment will be for a period of two years with the second year contingent upon the availability of funds. The positions may be filled on a rotating basis. Salary will be competitive. Send resume, statement of interest, and the names of three referees to Thomas A. Davies, Chief Scientist, Ocean Margin Drilling Program, Joint Oceanographic Institutions, Inc., 2600 Virginia Ave, NW, Suite 512, Washington, DC 20037. The deadline for applications is February 20, 1981, or as soon thereafter as suitable candidates are found.

Exploration Geophysics/University of Oklahoma. As part of a 5-year plan of development and expansion, the School of Geology and Geophysics is looking for a person to form the nucleus of an exploration geophysics group. A Ph.D. in geophysics is required, and preference will be given to someone whose teaching and research interests are in the acquisition, processing, and/or interpretation of seismic data. Present equipment includes a truck-mounted thumper energy source, capable of penetrating a kilometer or more of rock; a portable, 12-channel seismic recording system; gravimeters; magnetometers; an electrical resistivity unit; in-house mini-computers; and terminals to the University's IBM 370 system. A geophysical observatory supports research in solid earth geophysics, and the exploration geophysicist would work closely with the lecturer-solid earth geophysics group.

Applications are due by February 15, 1981. Salary is competitive with industrial standards. Inquiries and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma does not discriminate on the basis of race or sex and is an equal opportunity employer.

Drexel University/Atmospheric Scientist. Three tenure track faculty positions are anticipated starting Fall 1981. Applications are solicited from Ph.D.'s with independent research experience in one of the following areas of atmospheric science: general circulation; climate dynamics with application to satellite meteorology; atmospheric optics, experimental or theoretical with emphasis in mesoscale probing; boundary layer turbulence modeling; and atmospheric chemistry modeling. Rank and salary commensurate with experience. Send resume and references to Dr. William W. Elsbon, Head, Department of Physics and Atmospheric Science, Drexel University, Philadelphia, PA 19104.

An equal opportunity/affirmative action employer

Hydrologist. Sigma Data Computing Corp.'s Division of Information and Scientific Applications invites applications from hydrologists qualified to participate in an environmental modeling/chemical fate assessment team effort.

The applicant will evaluate terrestrial and groundwater models and their data requirements to form a comprehensive multimedia modeling library system for assessment of toxic chemicals. The applicant will also provide recommendations for modification of existing model algorithms and R&D for anticipated continuing model development.

An M.S. degree or equivalent experience is a minimum requirement. Programming experience in FORTRAN and use or development of water quality models is desirable but not essential.

Salary is commensurate with qualifications.

Please submit resume and reference to:

Roger Long
Sigma Data Computing Corp.
2021 K Street, NW
Suite 207
Washington, D.C. 20006

Scientific Analyst. Scientific analyst to conduct research in the remote sensing of the environment using radiative transfer techniques through satellites to analyze the composition of the atmosphere and temperature variations. Requires Ph.D. in physics, good knowledge of FORTRAN, and experience with IBM 360 computers.

Send resumes to: Rodger Smith, Manager of Staffing, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, MD 20840.

An equal opportunity employer.

Program Manager/Meteorology. Oceanographic Services, Inc., is seeking qualified applicants for the position of program manager for meteorological studies. Applicants should have an M.S. or Ph.D. in meteorology or atmospheric sciences, plus experience in the field. A broad general knowledge of air pollution, and an understanding of the air pollution regulatory environment, is helpful. Interested persons should send resume, references, and salary history to R. C. Banke, Oceanographic Services, Inc., 25 Castilian Drive, Goleta, CA 93117.

Graduate Assistantships/Physics and Astronomy. Graduate research assistantships and teaching assistantships in the Department of Physics and Astronomy at the University of Iowa are available to well-qualified students. The department has vigorous research programs in space physics, plasma physics, acoustics, astronomy, astrophysics, atomic physics, elementary particle physics, laser physics, nuclear physics, and solid state physics. Assistantships can begin in June, August, or January. Please address your inquiry to Department of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242.

Space Plasma Physicist. The space plasma theory group at UCLA has begun a program of numerical simulations of problems in space plasma physics. We seek a Ph.D. level theoretical plasma physicist with a record of accomplishment in plasma numerical simulations, as evidenced by publications, who is interested in theoretical research in magnetospheric physics. The applicant should have extensive experience in the design and implementation of plasma simulation codes, either kinetic or fluid. Prior experience with simulation of space plasmas is highly desirable. The position will be available September 1, 1981. Salary commensurate with experience and qualifications. Interested parties should send a curriculum vitae, bibliography and names of three suggested referees to Professor P. J. Coleman, Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, California 90024, with a copy to K. Olwin at the same address.

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AGU

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Semmis, Charles G.
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Schorb, Frank
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Schwartz, Chrnlos R.
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Vogel, Andreas
Voss, Joachim
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Wang, Herbert
Wetere, Kenneth H.
Wei, Chou
Whipple, Elden
Wioronga, Peter J.
Wilt, Michnol
Wright, James A.
Wu, Francis
Wyllie, Peter J.
Young, G. K.

Fun Run Results

Here are the results of the Geophysical Fun Run, held December 9 in San Francisco during the Fall Meeting. The tectonophysics section had the most participants, followed closely by seismology. Art Boettcher (VGP) placed first. The course was 4.3 miles, from the Marina, along the San Francisco Bay, to Ft. Point. Brian Bonner and Bill Brace officiated, and Eileen Schaffer helped with the organization.

Place		Time
1.	Art Boettcher, first master (over 40)	25:24
2.	Art Sylvester	26:00
3.	Leonard Johnson	27:27
4.	Tom Oey, first open runner	26:40
5.	Bill Dyer	28:43
6.	Rick Dttolini	29:00
7.	Tom Dixon	29:10
8.	Jim Hawkins	29:14
9.	Bob Gagoslan	29:40
10.	Chris Bernea	29:55
11.	Eileen Schaffer, first woman	30:00
12.	Bob Kiockhafer	31:05
13.	John Ross, first man over 50	31:25
14.	Robin Coley	32:00
15.	Detmar Schnitker	32:30
16.	Billian Turner	32:45
17.	Phil Helleck	33:00
18.	Ken Yamashima	33:20
19.	Jim Vernon	33:32
20.	Ahern Evister	34:03
21.	Jim Kirkpatick	34:50
22.	Randy Richardson	39:41
23.	Doris Vernon, first woman master	40:00
24.	Harmon Creig	late start

AGU SCHOLARSHIP ASSISTANCE FOR THE ACADEMIC YEAR 1980–1981

The June Bacon-Bercey Scholarship in Atmospheric Sciences for Women

Scholarship assistance in the amount of $400 will again be made available to a woman who intends to make a career in the atmospheric sciences. The award, which is provided through a gift from June Bacon-Bercy, a noted practicing meteorologist, will be made on the basis of academic achievement and promise. To be eligible for this scholarship a candidate must be one of the following at the time of application:

- a first-year graduate student in a program leading to an advanced degree in the atmospheric sciences;
- an undergraduate in a bachelor's program leading to a degree in the atmospheric sciences, who has been accepted for graduate study in the field; or
- a student at a 2-year institution offering at least 6 semester hours of atmospheric sciences, who has been accepted for a bachelor's degree program in the atmospheric sciences and who has completed all of the courses in atmospheric science offered at the 2-year institution.

Application forms are available from the American Geophysical Union, Member Programs Division, 2000 Florida Avenue, N.W., Washington, D. C. 20009 (202/462-6903). Selection of the awardee will be made by the AGU Subcommittee on Women in Geophysics, in consultation with the AGU Meteorology Section.

DEADLINE FOR RECEIPT OF APPLICATIONS IS MARCH 16, 1981

Meetings

Processing Remotely Sensed Data

A call for papers has been issued for the Seventh International Symposium on the Machine Processing of Remotely Sensed Data, scheduled for June 23–26 at the Purdue University Laboratory for Applications of Remote Sensing, in West Lafayette, Indiana. Special emphasis will be on forest, range, and wetland assessment.

Papers are solicited on but not restricted to data correction and enhancement, digital classification techniques, evaluation of classification results, forest resources inventory, rangeland assessment, wetlands and water resources, land use and geographic applications, crop inventory, soil survey, geology applications, georeferenced information systems, and technology transfer.

Four copies of paper summaries are due February 13. Summaries should be between 500 and 1000 words. Authors will be notified of paper selection by March 16. A camera-ready copy of the manuscript will be due June 26.

Send summaries to Douglas B. Morrison, Purdue University/LARS, 1220 Potter Drive, West Lafayette, Indiana 47906. ☒

Magnetospheric Data Assessment

The Scientific Committee for Solar Terrestrial Physics (SCOSTEP) will sponsor a symposium at the Goddard Space Flight Center in Greenbelt, Maryland, May 21–23, to assess data gathered under the International Magnetospheric Study (IMS).

Objectives of the conference, which is scheduled immediately before the AGU Spring Meeting in Baltimore, are to determine the availability of data needed for correlative IMS studies; to examine the scientific results of the various workshops; to analyze the strengths and weaknesses of the various workshop forms; and to identify the work required to fulfill overall IMS objectives.

The first day of the symposium will examine the data available for correlative purposes. Of greatest interest are data sets that cover a large fraction of the IMS time period (1977 to 1979). The second day will concentrate on the examination of scientific results from previous IMS workshops. On the final day, the scientific progress of the IMS analysis will be examined.

Further details about the symposium can be obtained from the convenors: C. T. Russell, Institute of Geophysics, University of California, Los Angeles, California 90024, and D. J. Southwood, Physics Department, Imperial College, London SW7, United Kingdom. ☒

New Listings

The complete Geophysical Year list appeared in the December 30 *Eos*.

Boldface indicates meetings sponsored or cosponsored by AGU.

1981

Mar. 9–12 ERRSAC/NOAA Land Remote Sensing Applications Conference, Danvers, Mass. Sponsors, NASA, NOAA. (Conference Management, Systems and Applied Sciences Corp., 6811 Kenilworth Ave., Riverdale, MD 20840.)

May 4–5 Seminar on Non-Sandstone Uranium Deposits, Golden, Colo. Sponsors, U.S.G.S., U.S. Department of Energy, Bendix Field Engineering Corp. (Geology Division, Bendix Field Engineering Corp., P.O. Box 1569, Grand Junction, CO 81502.)

June 23–26 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./LARS, 1220 Potter Dr., West Lafayette, IN 47906.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marefelipiatz 8, D-8000 Munchen 22.)

Sept. 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering. (R. Negle, Publicity Menager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water Resources Branch of Ontario's Ministry

of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, L7R 4A6, Ontario, Canada.)

Oct 26-31 International Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsor, Center for Coastal Studies of Scripps Institution of Oceanography. (D. L. Inman, Director, Center for Coastal Studies, Scripps Institution of Oceanography, La Jolla, CA 92093.)

1983

July 18-23 Fourth International Conference on Permafrost, Fairbanks, Alaska. Sponsors, National Academy of Sciences, State of Alaska. (L. Dr Goes, Polar Research Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

Sept. 12-14 National Water Well Association 35th Annual Convention and Exposition, St. Louis, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

1981 AGU Spring Meeting

Baltimore, the site of the AGU Spring Meeting, May 25-29, is enjoying a major urban renaissance. Nowhere is this more apparent than in Metro Center, the 1000-acre downtown core of Baltimore. The convention center, an ultramodern meeting facility, is only a short walk from Harbor Place. Harbor Place is a skylighted, terraced conglomeration of more than 20 waterside restaurants and over 100 boutiques.

Hotel Accommodation. A block of rooms is being held at three nearby hotels: the Baltimore Hilton, the Lord Baltimore, and the Holiday Inn-Downtown. The Lord Baltimore and the Hilton are connected by a covered walkway. Read the housing application and MAIL THE COMPLETED APPLICATION FORM TO THE HOUSING BUREAU early to insure confirmation of preferred hotel.

Registration. Everyone who attends the meeting must register. Preregistration (received by May 8) saves you time and money, and the fee will be refunded if AGU receives written notice of inability to attend by May 15. Registration rates are as follows:

	Preregistration	At Meeting (after 5/8)
Member	$45	$60
Student Member	$25	$40
Nonmember	$65	$85

Registration for 1 day only is available at one half the above rates. Members of the American Meteorological Society, the American Society of Photogrammetry, and the American Congress on Surveying and Mapping may register for the meeting at the AGU member rates.

Students who are not AGU members should send in an application form with their registration payment. The difference between member (or student member) registration and nonmember registration may be applied to AGU dues if a completed membership application is received at AGU by August 3, 1981. Current AGU annual membership rates are: $20 members; $7 student members.

To preregister, fill out the registration form, and return it with your payment to the AGU Office. When payment is made by an organization, please attach the form wherever possible; or be certain that your name and other pertinent information is on the check. Your receipt will be included with your preregistration material at the meeting. Preregistrants should pick up their registration material at the preregistration desk at the Convention Center. (On Sunday, from 5-8 P.M. in the lobby of the Hilton hotel).

The program and meeting abstracts will appear in the April 28 issue of *Eos*, which is mailed to all members in advance of the meeting.

Complimentary badges for guests not attending the scientific sessions will be available at the registration desk.

Social Events

An array of evening activities includes the Ice Breaker on Monday; the awards presentation honoring fellow scientists at a ceremony open to all participants, followed by a reception, on Tuesday; and an evening of fun and exploration on Thursday at the Maryland Science Center.

Business Luncheons

There will be eight section luncheons: Geodesy, Geomagnetism and Paleomagnetism, Hydrology, Oceanography, Planetology, Seismology, Solar-Planetary Relationships, and Volcanology, Geochemistry and Petrology.

Check the appropriate spaces on the registration form and indicate number of reservations. Details of these activities will be published from time to time in *Eos*. Follow the Sail Into Baltimore weekly update.

SAIL INTO Baltimore

AGU Spring Meeting
May 25-29

HOTEL ACCOMMODATIONS

PARTICIPATING HOTELS	*HOTEL CODE*	*ROOM RATES*
Baltimore Hilton Hotel 101 W. Fayette St. Baltimore, MD 21201 (301) 752-1100	BHDT	Single: $43.00 Double: $58.00 Twin: $50.00
Holiday Inn-Downtown 301 W. Lombard St. Baltimore, MD 21201 (301) 685-3500	HIDT	Single $35.00 Double: $38.00 Twin, $44.00
Lord Baltimore Hotel Baltimore & Hanover Streets Baltimore, MD 21201 (301) 539-8400	LBDT	Single: $33.00 Double: $39.00 Twin: $39.00

EXTRA PERSON

Hilton $15.00
Lord Baltimore $8.00
Holiday Inn $7.00

PARKING

Hilton nominal charge
Lord Baltimore nominal charge
Holiday Inn free

SUITES

Hilton
- Parlor plus one bedroom suite $125.00-$190.00
- Parlor plus two bedroom suite $250.00

Be sure to enter the appropriate code letters on the attached form. Keep this sheet for your records, and forward the housing application form to the housing bureau at the address indicated.

All hotel reservations must be made on the housing form by April 24, 1981. No telephone requests will be accepted. Confirmations will be mailed directly to registrants by the individual hotels. After confirmation has been received, changes should be made with the hotel directly. Cancellations should be made with the housing bureau.

Any questions regarding your hotel accommodations should be directed to:

Housing Coordinator
ABA Marketplace
Baltimore Housing Bureau
1 West Pratt St.
Baltimore, MD 21201
(301) 659-7000

PLEASE RETAIN THIS FORM FOR YOUR RECORDS

American Geophysical Union
Spring 1981 Meeting

May 25-29, 1981
Baltimore, Maryland

Mail this form to:
Housing Bureau
1 West Pratt St.
Baltimore, MD. 21201

HOUSING APPLICATION FORM

READ CAREFULLY:

Please print or type (place spaced) all information abbreviating as necessary. Confirmation will be sent by the hotel to the individual named in Part I. If more than one room is required, *this form may be photocopied.*

PART I

REQUESTOR
LAST NAME FIRST
NAME OF COMPANY OR FIRM
STREET ADDRESS OR P.O. BOX NUMBER
CITY STATE ZIP-U.S.A.
COUNTRY AREA CODE PHONE NUMBER

PART II

INSTRUCTIONS: Select *THREE* Hotel/Motels of your choice from the list of participating facilities, then enter the appropriate code letters in the boxes below.

FIRST CHOICE HOTEL CODE
SECOND CHOICE HOTEL CODE
THIRD CHOICE HOTEL CODE

NOTE: Rooms are assigned in "First Come First Serve" order and if none of your choices are available, another facility will be assigned based on a referral system arranged by your convention organizer. A cut-off date is in effect and your application may not be processed if received after 14 days prior to your arrival date.

*AGU housing registration deadline is April 24, 1981

PART III

INSTRUCTIONS:
1. Select type room desired with arrival and departure dates.
2. *PRINT* or *TYPE* names of *ALL* persons occupying room.
3. If more than two people share a room, check twin and the hotel will assign two double beds.

CHECK ONE
- ☐ 1 SINGLE (Room with one bed one person)
- ☐ 2 DOUBLE (Room with one bed two persons)
- ☐ TWIN (Room with two beds two persons)
- ☐ P+1 (Parlor plus one-bedroom suite)
- ☐ P+2 (Parlor plus two-bedroom suite)
- ☐ EXTRA PERSON

Arrival Date MO DAY
Departure Date MO DAY
Arrival Time AM PM

Guest Names (Print Last Name First)
1.
2.
3.
4.

IMPORTANT NOTE: Hotel *MAY* require a deposit or some other form of guaranteed arrival. If so, instructions will be on your confirmation form.

AMERICAN GEOPHYSICAL UNION
1981 SPRING MEETING

Baltimore Convention Center
Baltimore, Maryland
May 25-29

Registration Form

RETURN THIS FORM WITH PAYMENT TO:
Meetings Registration
American Geophysical Union
2000 Florida Ave., N. W.
Washington, D. C. 20009

Office Use
Reference Number

DEADLINE FOR RECEIPT OF PREREGISTRATION—May 8, 1981
Days you plan to attend | | Monday | | Tuesday | | Wednesday | | Thursday | | Friday

PLEASE PRINT CLEARLY

Badge Identification

NAME ON BADGE

AFFILIATION

Name

Mailing Address

Telephone #

Address during the meeting if different than above

PREREGISTRATION (rates applicable only if received by May 8 deadline)

	More than one day	One Day
Member	☐ $45	☐ $22.50
Student Member	☐ $25	☐ $12.50
Nonmember	☐ $65	☐ $32.50
Abstracts April 28 (*Eos*) $5		

SPECIAL EVENTS

Check the appropriate spaces and indicate number of reservations. — No. of tickets

AGU AWARDS RECEPTION, following open presentation ceremony; includes food and drink, 7:30 p.m., Hilton. Cost per ticket: $9.25 — _____ Tuesday

SCIENCE CENTER: An evening of fun and exploration; includes food and beer, 8:30 p.m., Maryland Science Center. Cost per ticket: $8.50 — _____ Thursday

SECTION LUNCHEONS

Geodesy — _____ Wednesday
Geomagnetism and Paleomagnetism — _____ Thursday
Hydrology — _____ Wednesday
Oceanography — _____ Wednesday
Planetology — _____ Wednesday
Seismology—cost per ticket: $3.50 due to subsidy — _____ Thursday
Solar-Planetary Relationship — _____ Thursday
Volcanology, Geochemistry, and Petrology — _____ Thursday
Cost of ALL LUNCHEONS, $8.00 per ticket, unless otherwise noted

Please check appropriate box.
Members of the cooperating societies may register at AGU member rates
Member badges are blue on white
Nonmember badges are red on white
| | Member AGU | | Nonmember
| | Member cooperating society
AMS-American Meteorological Society
ASP-American Society of Photogrammetry
ACSM-American Congress on Surveying and Mapping

| | Payment enclosed
Charge to: | | Visa
| | Master Charge (Interbank)

Card Number
Interbank
Expiration Date
Signature

Other payments (Please identify) $
Total $

MAKE CHECK PAYABLE TO AGU

Office Use
Code
Check No

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To Order: The order number can be found at the end of each abstract; use all seven digits when ordering.

Cost: $3.00 for the first article and $1.00 for each additional article in the same order. Payment must accompany order.

Deposit Account: A minimum of $10.00 may be placed on deposit with AGU for the purchase of separates. If funds are on deposit, the cost of the first article is only $2.00 and $1.00 for each additional article in the same order.

Separates will be mailed within 3 weeks of journal publication or within 10 days if ordered after the journal has appeared. Separates are available for purchase for two years from date of publication.

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Send your order to: American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

Electromagnetics

0750 Optics
SINGLE-MODE PROPAGATION IN HALF-LAYER ELLIPTICAL FIBER WAVEGUIDES
A. W. Snyder, [Department of Electrical and Computer Engineering, California State University Northridge, Northridge, CA 91330] and J. E. Lewis. Single mode propagation in three-layer step index elliptical fiber waveguides is investigated numerically. Previous analysis of the elliptical dielectric tube waveguide is extended to include cladded, W-type and tube type fibers. Numerical results on cutoff characteristics of the first higher-order mode and phase coincident, group velocity and power distribution parameters of the dominant modes are presented over a wide range of parameters. A two-layer step index elliptical fiber waveguide is presented as a limiting case. High eccentricity single mode fibers have small modal beat lengths but have small core size and greater power distribution in the claddings. W-type fibers in the middle range of eccentricities is suggested for single mode single polarization applications. (Receive[illegible] Rad. Sci., Paper 1E0090

0765 Tropospheric propagation
CROSS POLARIZATION DURING CLEAR-AIR CONDITIONS ON TERRESTRIAL LINKS — A REVIEW
R.K. Crane, [Communications Research Centre, Department of Communications, Ottawa, Canada K2H 8S2]

This paper reviews experimental and theoretical research on cross polarization that occurs during clear-air conditions on terrestrial microwave links. After consideration of the various mechanisms (at least five have been suggested), this discussion is given that multipath mechanisms [illegible] dealing with the cross-polarized patterns of the antennas are the most important. Theoretical models that explain these mechanisms and semi-empirical models that characterize the cross-polarized signal statistics are then discussed. Particular attention is given to the semi-empirical models since they can be used most readily for statistical predictions in design applications. Some new insight into the similarities and differences between models developed in France, Japan, and the USA is provided. Finally, application of the semi-empirical models in the design of digital systems is briefly considered, and the relative importance of cross polarization during clear-air and precipitation conditions is discussed. [Cross polarization, clear-air] Rad. Sci., Paper 80E1794

0765 Tropospheric propagation
CROSS POLARIZATION DURING PRECIPITATION ON TERRESTRIAL LINKS — A REVIEW
R.L. Olsen [Communications Research Centre, Department of Communications, Ottawa, Canada K2H 8S2]

This paper reviews recent theoretical and experimental research on cross polarization that occurs during precipitation on terrestrial microwave links. Consideration is first given to the physical mechanisms, such as raindrop canting, that cause precipitation depolarization. Coherent rain depolarization models are then discussed and old versus[illegible] misalignments of incoherent depolarization effects summarized. Particular attention is given to semi-empirical models since they can be used most readily for statistical predictions in design applications. Model prediction and depolarization measurements are then compared. Cross-polarization measurements at a frequency of the rainfrop canting angle distribution derived from these measurements are tabulated. Finally, some methods for the[illegible] of the importance of rain depolarization and attenuation in causing outages on digital radio systems[illegible] cross polarization. [Precipitation] Rad. Sci., Paper 80E1795

Hydrology

[illegible] Transport and redistribution
SPECIES TRANSPORT IN FINE-GRAINED SEDIMENTS: AN SP-STUDY
M. Shafiqul Hoque, [Environmental Research Laboratories, 200 SW 35th Street, Corvallis, Oregon 97330] and R. Scott
This paper proposes a self-consistent procedure for evaluating redistribution rates on the stressed gravels used for spawning by salmonids. It establishes a relationship between average survival of incubating eggs and the geometric mean diameter of the substrate. It outlines simple procedures for evaluating the overall composition of the gravel by sieving sites along stream reaches and provides the rationale for interpretation of these estimates in terms of overall effects survival in a stream reach. (Salmonidae, salmonid spawning, particle size, stream gravel).
Water Resour. Res., Paper 80W1834

3130 Groundwater
[illegible] FLOW OF HYDROLOGICAL PROPERTIES
[illegible] HETEROGENEOUS AQUIFERS
[illegible]
Jack Meyer [Institute of Sedimental Sciences, Baltimore MD, Sarnoff Laboratory, Inwell, Oxfordshire, U.K.] and A. Bijl
A method for determining hydraulic conductivity/specific storage, using a sinusoidally varying pressure is proposed. It is based on the propagation of a pressure wave between point sets within an infinite region and pattern correlation which fully exists a confined aquifer. A solution in terms of sand extension and time lag is presented for cases of different hydraulic diffusivities and signals of various periods. These solutions are put into the context of actual test properties in order to determine the practical limitations of the discharge measuring to the equations shown and below the[illegible]. The potential for this flow field is referred to as the complementary potential and is determined by solving a boundary-value problem of the Poisson equation. Use of the complex variable method is possible to determine the piezometric heads along the edges of the[illegible] which the[illegible] for an iterative procedure. [Deposit-Fossil[illegible] Impervious laminae]
Water Resour. Res., Paper 80W1529

3130 Groundwater
MODELING DOUBLE ARTESIAN FLOW USING A COMPREHENSIVE POTENTIAL AND DISTRIBUTED SINGULARITIES
[illegible]SOLUTION FOR HOMOGENEOUS FORMATIONS
O.D.L.Strack [Department of Civil and Mineral Engineering, University of Minnesota, USA]
A technique is presented for modeling steady groundwater flow in aquifers that contain thin, impervious clay laminae. Assumptions is made in[illegible] that do not overlap one another. The technique is then applied to the[illegible] to flow in vertical direction is neglected like Dupuit-Forchheimer assumptions and that the thickness of the laminae can not[illegible] into account. The flow problems are solved by the use of an imaginary flow field with a discharge vector that consists of the vertical components of the discharge occurring in the aquifers above and below the laminae. The potential for this flow field is referred to as the complementary potential and is determined by solving a boundary-value problem of the Poisson equation. Use of the complex variable method is possible to determine the piezometric heads along the edges of the clay laminae which the need for an iterative procedure. [Deposit-Fossil[illegible] Impervious laminae]
Water Resour. Res., Paper 80W1529

3130 Groundwater
FLOW IN AQUIFERS WITH CLAY LAMINAE-THE COMPREHENSIVE POTENTIAL
O.D.L.Strack [Department of Civil and Mineral Engineering, University of Minnesota, USA]
A technique is presented for modeling steady groundwater flow in aquifers that contain thin, impervious clay laminae. Assumptions is made in[illegible] that do not overlap one another. The technique is then applied to the[illegible] to flow in vertical direction is neglected like Dupuit-Forchheimer assumptions and that the thickness of the laminae can not[illegible] into account. The flow problems are solved by the use of an imaginary flow field with a discharge vector that consists of the vertical components of the discharge occurring in the aquifers above and below the laminae. The potential for this flow field is referred to as the complementary potential and is determined by solving a boundary-value problem of the Poisson equation. Use of the complex variable method is possible to determine the piezometric heads along the edges of the clay laminae which the need for an iterative procedure. [Deposit-Fossil[illegible] Impervious laminae]
Water Resour. Res., Paper 80W1529

3130 Groundwater
SIMULATION OF COMPLEX GROUNDWATER SYSTEM AND AN APPLICATION
J. Premchit [Asian Institute of Technology, P.O. Box 2754, Bangkok, Thailand] A. Das Gupta
A simple quasi-three-dimensional flow model for the simulation of complex groundwater system has been developed taking into consideration the real basin characteristics; and combining the virtues of wood theoretical basis and simple approaches in mathematical manipulation and computer programming. The power and flexibility of the model have been demonstrated by its application to the groundwater basin in lower central plain of Thailand in connection with Bangkok land-subsidence study. The Pahsanfloor formation is considered to be a single hydraulically connected body stratified into model layers for convenience in the simulation. Any number of model layers can be incorporated with coupling through the leakage flux. The mathematical process has been simplified by neglecting the plain flow equipped storage, since an equivalent in a theoretical sense cannot be delineated in a large and complex groundwater basin. The coupling effect of the proposed model would be much less than the equivalent full three-dimensional model (Freeze, 1971; Gupta and Tanji, 1976) or quasi-three-dimensional model considering equivalent storage (Hantley & Brind, 1978).
Water Resour. Res., Paper 80W1411